Status of Dall's Sheep (Ovis dalli dalli) in the Northern Richardson Mountains

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Executive Summary

This report describes what is known of Dall's sheep in the Northern Richardson Mountains, based on results from scientific studies combined with the documented local and Traditional Ecological Knowledge of northern aboriginal people. Partners interested in this population have collaborated to draft a management plan for this Dall's sheep population, and this report follows the structure of the proposed plan (Cooperation, Population, Habitat, Harvest and non-consumptive uses, and Education and information exchange). This report also identifies knowledge gaps.

Dall's sheep in the Northern Richardson Mountains are located at the northeast extent of the species range. Fixed-wing and helicopter surveys to estimate the abundance and composition of this Dall's sheep population have been done periodically since the 1970s. Abundance estimates indicate this population was smaller in the 1970s (N < 500) and grew steadily during the 1980s and early 1990s, until it reached a peak in the mid 1990s (N ~ 1730). It has since consistently declined, although the rate of decline appears to have tapered off between 2003 (N = 756) and 2006 (N = 704), the 2 most recent surveys. Composition estimates revealed an average of 31 lambs per 100 nursery sheep (range: 13 – 44, SD: 11); however the timing of the surveys varied between years. Fluctuations in this population may be related to a combination of factors. The Northern Richardson Mountains are a very cold environment, and cold summers have been linked with decreased productivity in other populations, particularly when at high densities. In this area, other herbivores such as the Porcupine herd of barren-ground caribou (*Rangifer tarandus groenlandicus*), muskox (*Ovibus moschatus*), moose (*Alces alces*), ground squirrel (*Spermophilus parryii*) and snowshoe hare (*Lepus americanus*) also share the land with Dall's sheep and may compete for resources. Mortality due to predation is unknown, but potential predators in the Northern Richardson Mountains include: wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), golden eagles (*Aquila chrysaetus*), wolverines (*Gulo gulo*), foxes (*Vulpes vulpes*), lynx (*Lynx canadensis*), black bears (*Ursus americanus*), and potentially cougars (*Puma concolor*). Some Dall's sheep individuals were found to be host of lungworm parasites, but the population is believed to be overall in good condition.

Dall's sheep in the Northern Richardson Mountains move between various habitats during the year, depending on their reproductive status and the forage available to them. Dall's sheep generally remain in higher elevations, near escape terrain and wind-blown areas, but may venture to lower elevations to access water or mineral licks. They also appear to be faithful to summer and winter ranges. Temperature and precipitation in the Northern Richardson Mountains have recently increased, and the effects of climate change on this population and its habitat use are various and hard to predict. Moreover, although the ecological importance of the area has been recognized under land use plans and community conservation plans, there is a potential for oil, gas or mineral development in the future.

Most of the harvest of this Dall's sheep population is by aboriginal hunters, although there is a small resident hunt on the Yukon side, and a general interest by some parties in developing sport hunting on the Northwest Territories side. Known harvest of this population indicates that most of the harvest has occurred on the Northwest Territories side. Harvest levels reported in the 1970s were regarded as unsustainable and were much greater than the levels reported in recent years. It is important to know about the number, sex, age, harvest location and date of sheep harvested in the Northern Richardson Mountains as such information can help to evaluate the sustainability of current harvest levels. Most residents of the surrounding communities value the presence of this population. Non-consumptive uses include viewing opportunities, photography, and adventure tourism.

Involving the communities in the management and research of Dall's sheep in the Northern Richardson Mountains is believed to be an important step towards the long-term conservation of this population. Suggested activities include: participation of community members in field studies; visits and public talks by Dall's sheep researchers and elders in school and community halls; school trips taking students into the sheep range; updates from renewable resource officers and councils to the communities; documentation of local and traditional ecological knowledge; and frequent exchanges about the status and concerns related to this population.

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Preamble

This status report pertains to the Dall's sheep (*Ovis dalli dalli* Nelson 1884) population living in the Northern Richardson Mountains, located in the Arctic[1], at the border between the Yukon and the Northwest Territories. Combining results from scientific studies with the local and Traditional Ecological Knowledge of northern aboriginal people, this report summarizes what is known about this population, describes its current status, and identifies information gaps. The need for this status report was established early in the development of the *Management Plan for Dall's Sheep in the Northern Richardson Mountains* because of its potential to assist in determining research priorities and management activities. Status report completion was prescribed as an action item of the plan (Element 2: Population Monitoring; Action 1), and, as directed by the members of the Working Group, its structure follows closely that of the management plan. This version was written for wildlife managers, researchers and other interested parties, and may include some technical content.

After a brief introduction covering Dall's sheep taxonomy, distribution, physical description and some natural history traits, this report is divided into the same elements as the *Management Plan for Dall's Sheep in the Northern Richardson Mountains*:

1. Cooperation: Describes the context for Dall's sheep management in the Northern Richardson Mountains; reviews the co-management process; and lists the involved stakeholders.

2. Population: Examines what is known of the evolution and genetics of this population; estimates its size, composition, trends, and productivity based on previous studies and traditional knowledge; and assesses the importance of various limiting factors.

3. Habitat: Describes the habitat of the Northern Richardson Mountains; reviews information about habitat use and movements of Dall's sheep; describes mineral licks; and identifies main land uses, development, and climate change issues.

4. Harvest and Non-Consumptive Uses: Summarizes how people have depended on this population historically; estimates the contemporary harvest levels; and discusses conservation concerns and the estimated impact of harvest.

5. Education and Information Exchange: Highlights the importance of educational programs and outreach activities designed to improve awareness of this Dall's sheep population among local communities.

[1] Above the Arctic Circle.

For elements 2, 3 and 4, knowledge gaps are identified at the end of each section and listed in the Appendix A. Please note that the gaps and suggestions made in this report represent the current view of the authors, but shall be revisited in the next draft of the Management Plan.

Introduction

Classification and Distribution

Mountain sheep are ungulate members of the order Artiodactyla, sub-order Ruminantia, Bovidae family, and genus *Ovis*. There are 2 species of mountain sheep in North America: bighorn sheep (*Ovis canadensis*), found mainly in the Canadian and American Rockies, extending from central Alberta and British Columbia to areas of the southern United States and northern Mexico; and thinhorn sheep (*Ovis dalli*), found in mountainous regions of northern British Columbia, the Yukon, Northwest Territories, and Alaska. Thinhorn sheep can be further divided into 2 subspecies: Dall's sheep (interchangeably written Dall sheep, *Ovis dalli dalli* Nelson 1884), present on the northern portion of the species range, and Stone's sheep (or Stone sheep, *Ovis dalli stonei* J. A. Allen 1897), found in the southern portion of the range (see Figure 1 for an illustration of the species distribution). Two additional subspecies, *O. d. kenaiensis* and *O. d. fannini*, were also defined in earlier literature (Cowan 1940), but their use is now questionable and current taxonomy is generally limited to *O. d. dalli and O. d. stonei*. The Gwich'in name for Dall's sheep is *divii* (Gwich'in Elders 1997) and the Inuvialuit name for sheep is *imnaiq* (Lowe 2001). The name Dall's sheep originates from William Healy Dall (1845–1927), an American naturalist who described observations of mountain sheep during his travels in Alaska and in the Yukon.

The Dall's sheep population of the Northern Richardson Mountains, the subject of this status report, is isolated at the northeastern limit of the species distribution (Figure 2). As such, exchanges with other populations are limited, and this population may be particularly sensitive to habitat or population disturbances. The nearest population is located in the Southern Richardson Mountains, approximately 75 km south. The population in the Southern Richardson Mountains was divided into two: a small dispersed group around Canyon Creek was counted at 19 in 1977, then at 24 in 1988 (Hoefs 1978, Barichello *et al.* 1987); and a larger group located in the Mt. Cronin area (including the Rock River crossing). The Cronin group was surveyed a few times between 1977 and 1988, with counts ranging between 40 and 107 and the most recent estimate being 66 in 1988 (Hoefs 1978, Barichello *et al.* 1987). Despite the relatively short distance between the populations in the Southern and Northern Richardson Mountains, the exchange rate between them is unknown. These populations have therefore been considered distinct and managed as

such. The population in the Southern Richardson Mountains has been subject to few investigations, and the need for better monitoring was recognized during the management planning for the Northern Richardson population.

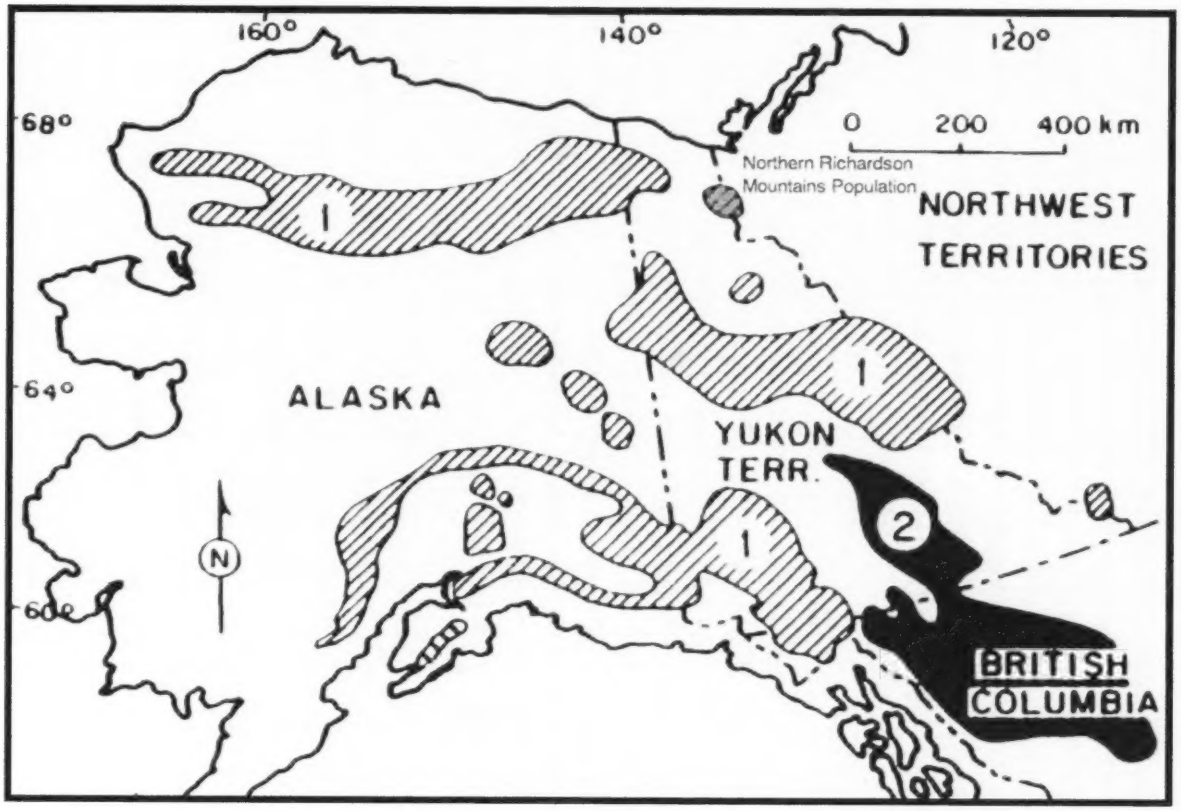


Figure 1. Thinhorn sheep distribution: (1) Dall's sheep and (2) Stone's sheep, adapted from Bowyer and Leslie (1992) (originally adapted from Hoefs (1985) and Nichols (1978)). The population of the Northern Richardson Mountains is highlighted in red. The distances on this map are approximate.

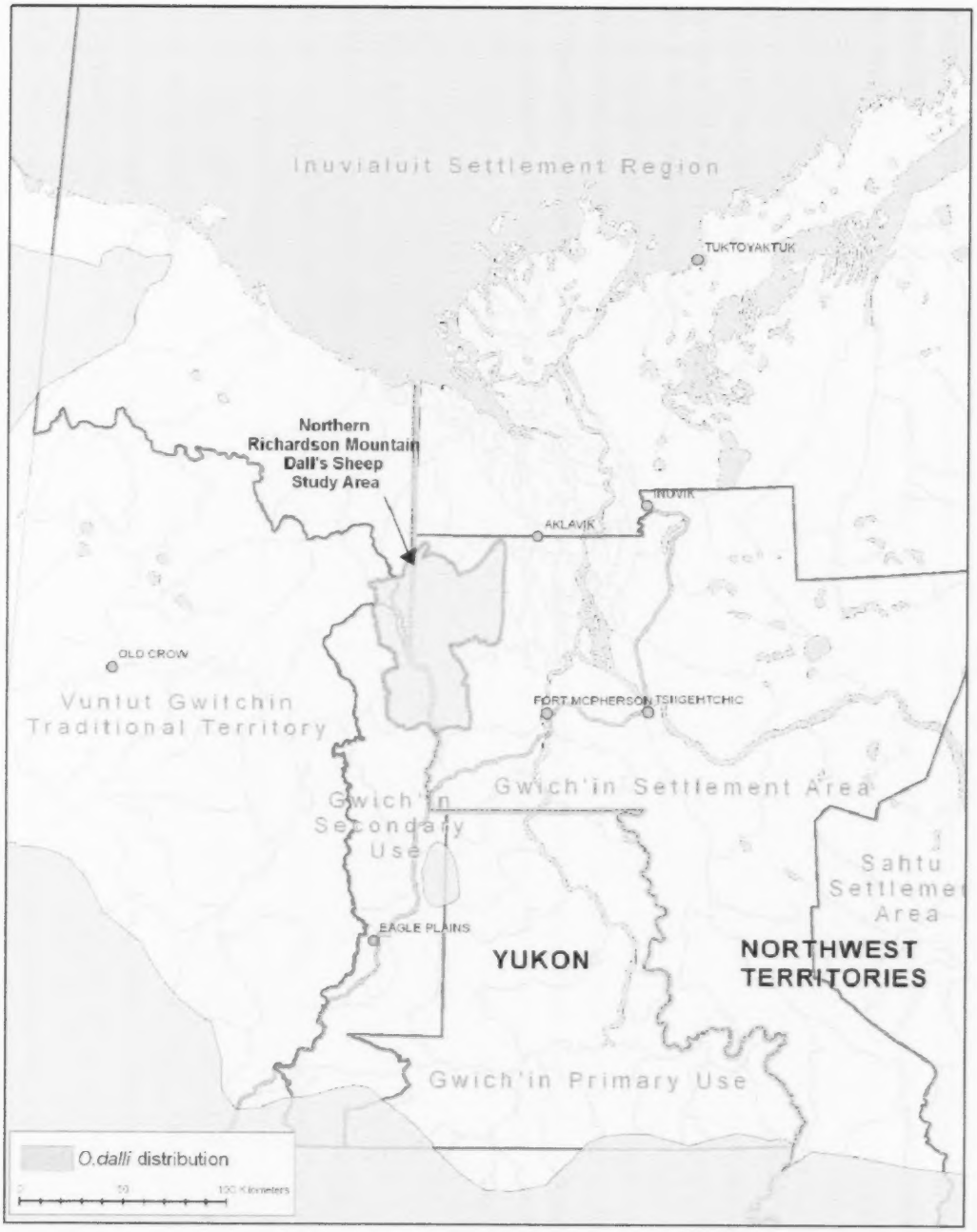
Physical Description and Natural History Traits

Dall's sheep is an animal of the alpine, found in the most rugged and mountainous environments of northern North America. Males and females are sexually dimorphic, as rams are heavier and bear larger horns than ewes (Cowan 1940, Bowyer and Leslie 1992). Each winter, except during their first, the cessation of horn growth creates an annual ring (segment) on the horn, which can be counted to accurately estimate the age of the individuals. Based on a bighorn sheep study, this aging technique is reliable for rams, but may only provide a minimal age for ewes (Geist 1966). Horn growth is related to age and body condition, which in turn is influenced by resource availability.

As such, northern sheep tend to have smaller horns than southern populations (Hoefs 1984*a*). Adult sheep are about 1.2 m high (Gwich'in Elders 1997) and measured males' height, at the shoulder, ranges from 916 to 1090 mm (Bowyer *et al.* 2000). Body weight is generally at its peak in late summer, and averages 74 kg for adult rams and 56 kg for adult ewes (Nichols and Bunnell 1999).

Dall's sheep have evolved in remarkably cold environments, and their coat (along with that of Arctic fox (*Alopex lagopus*)), was found to have the best insulating properties when compared to other northern mammals, including ringed seal (*Phoca hispida*), wolf (*Canis lupus*) and polar bear (*Thalarctos maritimus*) (Scholander *et al.* 1950). The pelage of Dall's sheep is creamy white and their thick winter coat, which is shed in the spring (Cowan 1940), tends to be whiter than their slightly tan summer coat (Gwich'in Elders 1997), perhaps because of the dirtier environment in the summer time. Individuals at the southern part of the subspecies range exhibit a darker grayish variation (Cowan 1940).

Dall's sheep are primarily grazers of a variety of plants composed mostly of grasses and sedges (Nichols and Bunnell 1999). No formal investigation has been done of the diet of Northern Richardson Mountains sheep but it is likely similar to other thinhorn sheep populations. In Alaska, Dall's sheep diet was estimated at 66% grasses and sedges, 17% browse and forbs, 10% lichens, and 7% moss; lichen consumption appeared to increase during the winter (Nichols 1978*b*).



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1.0. Cooperation

1.1. Management Context

The Northern Richardson Mountain Dall's sheep range straddles Yukon and the Northwest Territories and overlaps the Gwich'in Settlement Area, the Gwich'in Secondary Use Area, the Inuvialuit Settlement Region, and the Vuntut Gwitchin First Nation Traditional Territory. The nearest human settlements are Aklavik and Fort McPherson, located about 20 km east and 50 km southeast from the margin of the Northern Richardson Mountains, respectively. The next closest settlements are Inuvik and Tsiigehtchic, Northwest Territories to the east, and Old Crow, Yukon to the west. As such, management of this population involves multiple parties and is subject to various legislation: the Northwest Territories Wildlife Act, the Yukon Wildlife Act, the Inuvialuit Final Agreement (adopted in 1984), the Gwich'in Comprehensive Land Claim Agreement (adopted in 1992), and the Vuntut Gwitchin First Nation Final Agreement (adopted in 1993).

The need for a management plan for this Dall's sheep population first emerged after early studies on this population. There were concerns about overharvest (Simmons 1973), gas pipeline proposals (Hoffman 1974), and the construction of the Dempster Highway (related mostly to the population in the Southern Richardson Mountains) (Hoefs 1978). After a series of population surveys (Males 1980, Latour 1984*b*) and the completion of a 3-year study on the dynamics, habitat use, and movements of this population (Barichello *et al.* 1987), a management plan was drafted in 1989 by the governments of the Northwest Territories and the Yukon. However, the document was never adopted and the initiative lay dormant for several years. Coincident with population surveys in 1991, 1997, 2001, and 2003 (Davison and Cooley 2006, Nagy and Carey 2006*a*, 2006*b*, Nagy *et al.* 2006*a*, Nagy *et al.* 2006*b*), local communities and wildlife authorities repeatedly recognized the need for a plan (Shaw *et al.* 2005). Finally, in 2005, interested parties met in Dawson City and in the spirit of co-management, the group reaffirmed the need for a management plan for Dall's sheep in the Northern Richardson Mountains.

1.2. Stakeholders and Planning Process

Partners involved in the management and conservation of the Dall's sheep population in the Northern Richardson Mountains include the following governments, co-management boards, and councils:

- Vuntut Gwitchin Government

- Gwich'in Tribal Council
- Inuvialuit Game Council
- North Yukon Renewable Resources Council
- Gwich'in Renewable Resources Board
- Wildlife Management Advisory Council (North Slope)
- Ehdiitat Gwich'in Renewable Resources Council
- Tetlit Gwich'in Renewable Resources Council
- Gwichya Gwich'in Renewable Resources Council
- Nihtat Gwich'in Renewable Resources Council
- Inuvik Hunters and Trappers Committee
- Aklavik Hunters and Trappers Committee
- Yukon Fish and Wildlife Management Board
- Yukon Government
- Government of Northwest Territories

The goal of this planning process was to secure the long-term conservation of Dall's sheep and its habitat in the Northern Richardson Mountains, as well as to provide for traditional and other uses that benefit all people.

A Working Group was designated to write the management plan, and a facilitator was hired to guide the planning process. The objectives, as outlined in a Terms of Reference, were (1) to recognize and protect the rights of aboriginal users as set out in the Inuvialuit Final Agreement, the Gwich'in Comprehensive Land Claim Agreement, and the Vuntut Gwitchin First Nation Final Agreement, while providing appropriate access and recognition to other lawful harvests and non-consumptive users; (2) to recommend to the appropriate responsible parties a 5-year management plan for the Northern Richardson Mountains Dall's sheep population and its habitat; (3) to recommend a process of shared responsibility for the implementation of the plan; and (4) to promote and strengthen communication and sharing of information among all groups interested in or affecting the management of the Northern Richardson Mountains Dall's sheep population and its habitat.

Following the initial meeting in 2005, a series of community consultations and meetings of the Working Group were held from 2006 to 2009. Interested community members, including elders and youth, participated in the management meetings. Currently, the management plan has yet to be formally adopted, but it has been presented to and discussed with most parties. The management plan lays out ways to ensure that cooperation continues between all parties responsible for the management of Dall's sheep in the Northern Richardson Mountains. This status report was commissioned as a way to summarize knowledge available on each section of the plan and to highlight information gaps.

2.0. Population Monitoring

2.1. Evolution and Genetics

It is believed that thinhorn sheep, bighorn sheep and the Siberian snow sheep (*Ovis nivicola*) had a common ancestor in the early Pleistocene or late Pliocene (Cowan 1940). During the last ice age, the thinhorn sheep ancestor probably crossed to North American from Asia, through the Bering Land Bridge, and occupied a large ice-free region in Yukon and Alaska, known as Beringia (Pielou 1991). Beringia, as well as other smaller ice-free regions in British Columbia, are believed to have acted as refugia for thinhorn sheep populations, and to be partly responsible for today's genetic diversity observed between subspecies of thinhorn sheep (Loehr *et al.* 2006). The Richardson Mountains were located at the easternmost limit of Beringia, and were marked by 3 marginal glacial events during the Quaternary period, covering portions or the totality of the range (Catto 1996). This marginal ice was melted approximately 12,000 years ago (Dyke and Prest 1987), and Dall's sheep could have inhabited the entire region since then.

Although the genetic structure and diversity across various thinhorn sheep populations in Alaska, the Yukon, and the Northwest Territories was recently investigated (Worley *et al.* 2004), the genetics of the population in the Northern Richardson Mountains have not yet been examined. Nevertheless, one could speculate that its genetic structure adheres to the isolation-by-distance pattern observed in other populations (Worley *et al.* 2004). As such, because of this population's relative isolation from other mountain ranges, its gene flow might be fairly restricted and its genetic variability correspondingly low, in comparison to more abundant populations living on a larger inter-connected range, such as the Mackenzie Mountains, Northwest Territories. This hypothesis remains to be verified. Investigating the genetic structure of this population could bring additional insights about its level of isolation, its degree of exchange with other populations, and its evolutionary history.

Knowledge Gap:

- The genetic structure of this Dall's sheep population and its genetic relationships with other thinhorn sheep populations has not been investigated.

2.2. Population Parameters

Abundance

Historical Trends Based on Local and Traditional Ecological Knowledge

For the past centuries, aboriginal peoples inhabiting or traveling through the Richardson Mountains were likely aware of Dall's sheep population cycles and shifts in composition. This information has, however, not been systematically recorded and is mostly unavailable. Nevertheless, some local and traditional ecological knowledge from Gwich'in elders and harvesters was documented in 2000 and 2001 when interviews were conducted in Aklavik, Fort McPherson, and Inuvik (Shaw *et al.* 2005). From observations recalled by the interviewees, no Dall's sheep population trend was clearly apparent between the 1950s and the 1990s, although a few participants mentioned that the population was larger at the time of the interviews than before, which would correspond to the population peak of the late 1990s estimated from aerial surveys, as described in the following sections. No information prior to the 1950s was mentioned. A more recent study (2008) documenting the traditional ecological knowledge of Dall's sheep, grizzly bears (*Ursus arctos*) and wolves in the Richardson Mountains was initiated with elders and harvesters from Aklavik and Fort McPherson. Some questions from this study related to the historical abundance and population dynamics of Dall's sheep, which should bring additional insights (C. Lambert Koizumi, Gwich'in Renewable Resources Board and University of Alberta, in preparation).

Earlier Surveys: The 1970s until mid 1980s

A series of surveys were conducted in the early 1970s and 1980s, which helped to delimit the distribution of this Dall's sheep population, estimate its abundance (summarized in Table 1), and acquire some baseline ecological information in the face of potential threats to itself or its habitat (e.g. via overharvest (Simmons 1973), potential pipeline development (Hoffman 1974, Nolan and Kelsall 1977), and construction of the Dempster Highway (Hoefs 1978)). Hoefs (1978) subdivided Dall's sheep range in the Northern Richardson into two: the "Mt. Goodenough" range, delimited by Black Mountain to the east, Willow River and the headwaters of Cache Creek to the north, Bell River to the west, and Rat River to the south; and the "Mt. Millen" population, covering the Mount Millen area, Sheep Creek area, and south of Summit Lake and the Rat Pass. This distinction was kept in subsequent surveys (Males 1980, Latour 1984*b*). These 2 regions as well as the areas covered during the surveys are shown in Figure 3.

For these earlier surveys, observers in fixed-wing aircrafts

(1971, 1979, and 1983) were not able to accurately distinguish the sex and age class, and instead focused on the total number of sheep. Observers in helicopters, however, attempted to categorize the individuals into the following groups: adult rams, adult ewes, yearlings, and lambs. Because of the difficulty involved in distinguishing between yearlings and ewes from the air, and to minimize harassment from repeated overflights (Nolan and Kelsall 1977), the 2 groups were often merged and referred to as "nursery sheep". The nursery sheep group may also include a small number of 2-year-old rams (Nichols 1978*b*). These survey estimates were not corrected for observation error, except for Males (1980), who inflated his observed sheep number by 25% to account for unseen sheep. To facilitate the comparison and be consistent with other surveys, numbers in Table 1 represent only actual counts.

In addition to the numbers presented in Table 1, Nolan and Kelsall (1977) conducted 3 aerial and 1 ground survey of the Black Mountain and surrounding areas during May and June 1973, to delineate lambing areas and estimate productivity. The number of sheep they counted ranged widely (from 37 to 122 within a week) and is not presented here. A 1-day survey was also reportedly conducted in February 1974 over the Black Mountain winter range, by Hoffman (as reported in Hoefs 1978, Males 1979; and authors' notes) and yielded a count of 47 (original document not located).

The sheep numbers reported between 1971 and 1984 show substantial fluctuations, which is likely due to a combination of various factors; the use of various methods (fixed-wing, helicopter, and snowmobile), the inconsistent timing of the surveys, and most importantly, the difference between survey areas (see Figure 3). This high variation may preclude comparing the estimates from this period to analyse the long-term population growth of Dall's sheep in the Northern Richardson Mountains. Nevertheless, some surveys intensively covered most of the Northern Richardson Mountains (in 1972, 1973, 1977, and 1979), and all reported a fairly small sheep population (<500, and most were <200). Previous authors (Simmons 1973, Hoefs 1978, Males 1980) were concerned that this population was small, potentially declining, and likely overharvested.

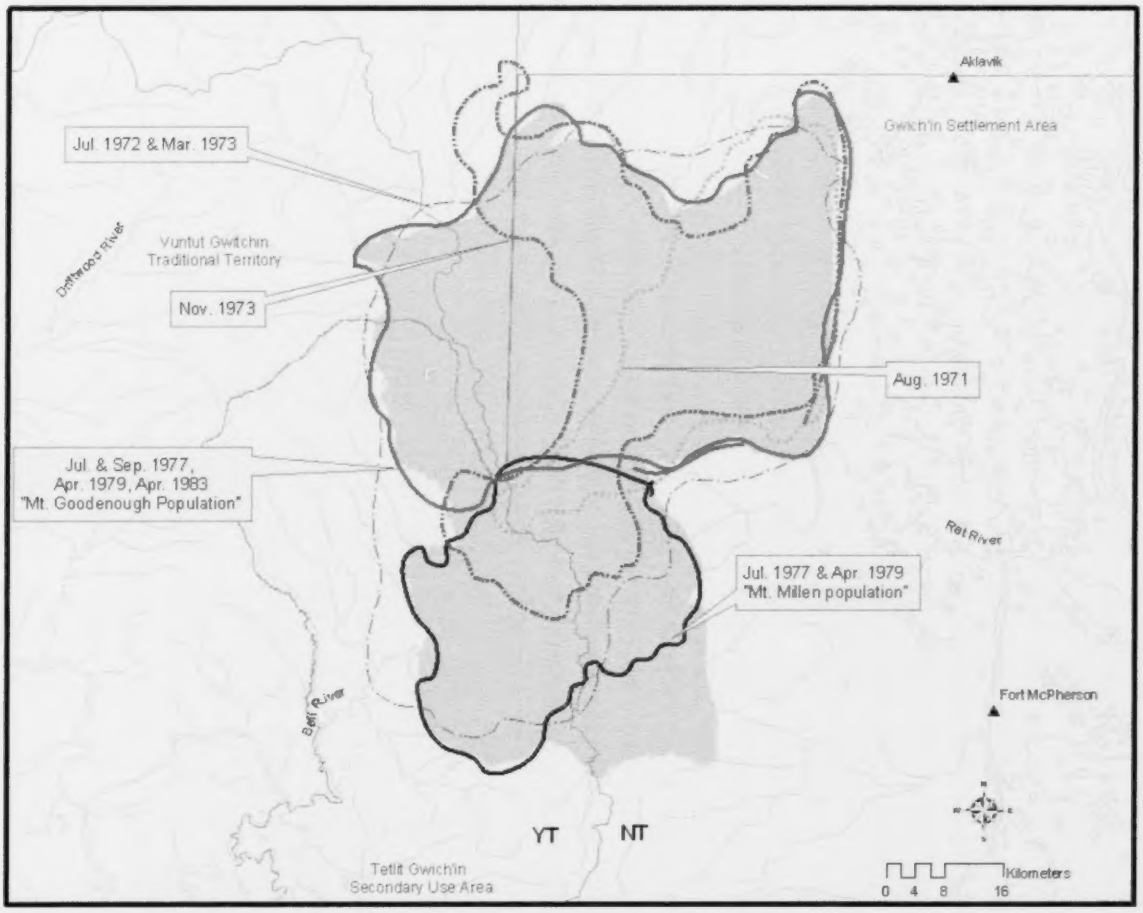

Figure 3. Approximate limits of the area covered by some previous surveys of Dall's sheep in the Northern Richardson Mountains (based on: Simmons 1973, Nolan and Kelsall 1977, Hoefs 1978, Males 1980, Latour 1984b). The grey shaded area delimits the current survey area (since 1997).

Table 1. Dall's sheep estimates from earlier surveys (1971 to 1984) in various areas of the Northern Richardson Mountains. The nursery sheep group includes adult ewes, yearlings of both sexes, and potentially young rams who looked like ewes when viewed from the air. "*Unc.*" stands for unclassified sheep.

Year	Month	Method	Rams	Nursery Sheep	Lambs	Unc.	Total	Area Covered	Source
1971	Aug	Fixed-wing	37	---	---	---	193	Yellow line in fig.3	Simmons 1973
1972	Jul	Helicopter	105	222	34	89	450	Red line in fig.3	Nolan and Kelsall 1977
1973	Mar	Helicopter	30	60	25	4	119	Red line in fig.3	Nolan and Kelsall 1977
1973	Nov	Helicopter	49	61	27	3	140	Green line in fig.3	Nolan and Kelsall 1977
1977	Jul	Helicopter	46	121	48	---	215	Blue lines (fig.3: "Mt. Goodenough & Mt. Millen")	Hoefs 1978
1977	Sep	Helicopter	33	107	42	---	182	Bright blue line (fig.3: "Mt. Goodenough")	Hoefs 1978
1979	Apr	Fixed-wing	---	---	---	---	152[a]	Blue lines (fig.3: "Mt. Goodenough & Mt. Millen")	Males 1980
1983	Apr	Fixed-wing	---	---	---	---	68	Bright blue line (fig.3: "Mt. Goodenough")	Latour 1984a
1984	Mar & Apr	Snowmobile	---	---	---	---	130[b]	Black Mountain, Mt. Lang, and "Fish Hole" areas	Latour 1984b

Notes: [a] Observed number of sheep, however Males judged that a 25% correction factor was needed to account for unseen animals and presented an estimate of 190; [b] Pooled observations of 3 crews over a 1-month period (in 3 different areas).

Later Surveys: 1984 to 2006

The concerns about the low abundance of this Dall's sheep population during the early 1980s, combined with an interest in the region for oil and gas development, led to a comprehensive study on its population ecology, range use, and movements between 1984 and 1986 (Barichello et al. 1987, Barichello and Carey 1989). This was also the start of a series of more standardized surveys. Barichello and colleagues surveyed the Dall's sheep population by helicopter in June, July and March of 1984–1986, along the mountain contours and drainages (as described in Hoefs 1978) of the Northern Richardson Mountains, and partitioned the area into 11 survey blocks which have been used since then. A 12th block, Sittichinli, was added in 1997 following a request from Fort McPherson residents (survey blocks are mapped in Figure 4); however sheep have not yet been observed in this block during the aerial surveys. As in the previous helicopter surveys, Dall's sheep were classified either as: lamb, nursery sheep (ewes, yearlings and some 2-year old rams mixed with the group), and rams, which were further classed as into 1/2 curl, 3/4 curl or full curl (see Table 2 for results). Including an additional 10% to account for observation error or unseen sheep, the total population estimates for 1984, 1985, and 1986 were 597, 690, and 882 respectively. The trend observed during this period indicates a rapid population increase (15% and 27% annual increment in 1985 and 1986, respectively). Another survey done in 1987 yielded a count of 645 Dall's sheep (Stenhouse and Kutny 1987). The authors reported lower survey efforts on the Yukon side compared to 1986, and concluded that the population was either stable or increasing.

Subsequent population surveys (1991, 1997, 2001, 2003, 2006) were not adjusted for observation error, as Barichello *et al.* (1987) had done, but were consistently flown in the same area by helicopter, either in June or August. The 1991 survey estimated the population at 1374, with a high lamb to nursery sheep ratio (see productivity section), and more sheep found in the Goodenough, Sheep, Lick and Rat block surveys (Nagy and Carey 2006*a*). The 1997 survey counted 1339[2] sheep for 9 survey blocks (Nagy and Carey 2006*b*); however 3 blocks, the Millen, Bear and White blocks, could not be flown due to bad weather. When the 1997 estimate was adjusted based on the percentage of sheep found in these 3 blocks during the 1991 survey, the total came to 1730, which was the highest population abundance estimated to date. This said, the proportion of sheep in the different blocks in 1991 might not be an accurate indicator of the distribution in 1997; but, lacking the actual data for the 3 unsurveyed

[2] The reported total in Nagy and Carey (2006*b*) was 1344; but after calculating the sum of the survey counts presented in their report, the total was reassessed at 1339.

blocks of 1997, it is the best approximation available. The population declined thereafter, with 1057 sheep counted in June 2001 (Nagy *et al.* 2006*b*), 756 in August 2003 (Nagy *et al.* 2006*a*), and 704 in 2006 (Davison and Cooley 2006).

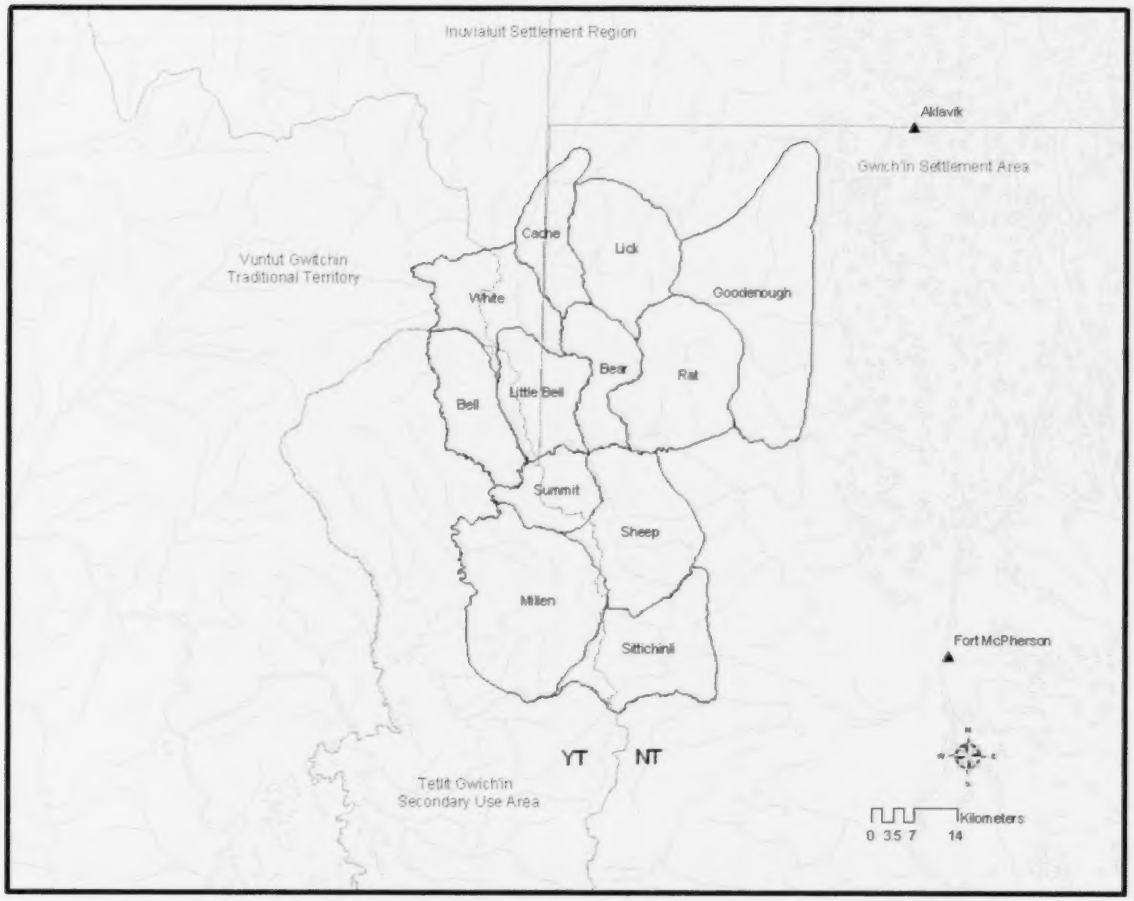

Figure 4. Current survey blocks for Dall's sheep in the Northern Richardson Mountains, as established in 1984 (with the exception of the Sittichinli block, added in 1997).

Table 2. Dall's sheep abundance estimates in the northern Richardson Mountains from aerial surveys conducted in helicopter between 1984 and 2006. The nursery sheep group includes adult ewes, yearlings of both sexes, and potentially young rams who looked like ewes when viewed from the air. "*Yrl.*" stands for yearlings, "*Unc.*" for unclassified sheep, and "*Est. Total*" for estimated total, which are the best estimates provided by the authors of each survey.

Year	Month	Rams				Nursery Sheep	Ewes	Yrl.	Lambs	Unc.	Raw Count	Est. Total	Source
		1/2 curl	3/4 curl	Full curl	Total								
1984	Jun	48	33	49	131[a]	302	234	68	110	---	543	597[b]	Barichello *et al.* 1987
1985	Jun	46	49	51	148[a]	362	256	106	117	---	627	690[b]	Barichello *et al.* 1987
1986	Jun	78	50	67	197[a]	460	309	151	145	---	802	882[b]	Barichello *et al.* 1987
1987	Jun	60	42	49	151	310	---	---	143	41	645	645	Stenhouse and Kutny 1987
1991	Aug	99	92	182	373	675	---	---	289	37	1,374	1,374	Nagy and Carey 2006*a*
1997	Aug	76	74	136	286	802	---	---	250	1	1,339	1,730[c]	Nagy and Carey 2006*b*
2001	Jun	43	55	133	231	734	---	---	92	0	1,057	1,057	Nagy *et al.* 2006*a*
2003	Aug	35	42	100	177	429	---	---	121	29	756	756	Nagy *et al.* 2006b
2006	Jun	21	20	60	101	460	438	22	97	46	704	704	Davison and Cooley 2006

Notes: [a] There were 1 unclassified ram in 1984, 2 in 1985, and 2 in 1986; [b] Adjusted by 10% to account for unseen sheep; [c] Adjusted to account for 3 blocks that could not be surveyed.

Population Trends

Because of the disparity in methods, area covered, and time of the year of the earlier surveys (Table 1), we excluded them from our analysis of population trends and abundance. This being considered, the July 1972 and July 1977 surveys were performed with a helicopter, at a similar time of year as the surveys conducted after spring 1984, and covered an area only slightly smaller. As such, they were incorporated with later surveys to assess the trajectory of this population between 1972 and 2006 (Figure 5). The resulting time series indicates a small population in the 1970s growing steadily during the 1980s and early 1990s, until it reached a peak in the mid 1990s, then declined consistently thereafter, although the rate of decline between 2003 and 2006 (the 2 most recent surveys) appears to have tapered off. An examination of a population's rate of growth over time can aid in explanations of proximate causes for changing population trends and may assist in predicting future trends. To this end, we calculated the realized population growth rate (λ) between each consecutive population survey.

The realized population growth rate λ between each consecutive population survey was calculated as $\lambda = (N_{t+T} / N_t)^{1/T}$, where T is the time interval in years and N represents the authors' population estimates for each survey (Case 2000). A λ value of 1 indicates that the population is stable; a value above 1 indicates it is growing; and a value below 1 indicates it is declining. As such, λ assists managers in assessing at-risk populations and when compared to population size, can aid in determining need for quick recovery actions (i.e. there is likely less time available for taking recovery actions for populations with both low λ and small population size). As shown in Figure 6, estimated annual realized growth rates for the 11 included surveys were variable over the 3 decades of monitoring, ranging from 0.73 to 1.28, with a geometric mean of 1.00 and a standard deviation of 0.18. Growth rates prior to 1991 were mostly indicative of an increasing population, interrupted by a drop below 1 between 1986 and 1987, possibly a result of the limited coverage of the 1987 survey. The rates also reflect a declining population for the most recent 9 years of monitoring. More frequent surveys would help refine these estimates. Moreover, to further analyze the viability and trajectory of this population, processes such as density-dependence, environmental and demographic stochasticities, and observation error, would need to be considered. A well-designed population viability analysis could provide a proper framework for further analysis of the fluctuations in abundance of this population (Boyce 1992, Morris and Doak 2002) and may better assist in predicting future population trends.

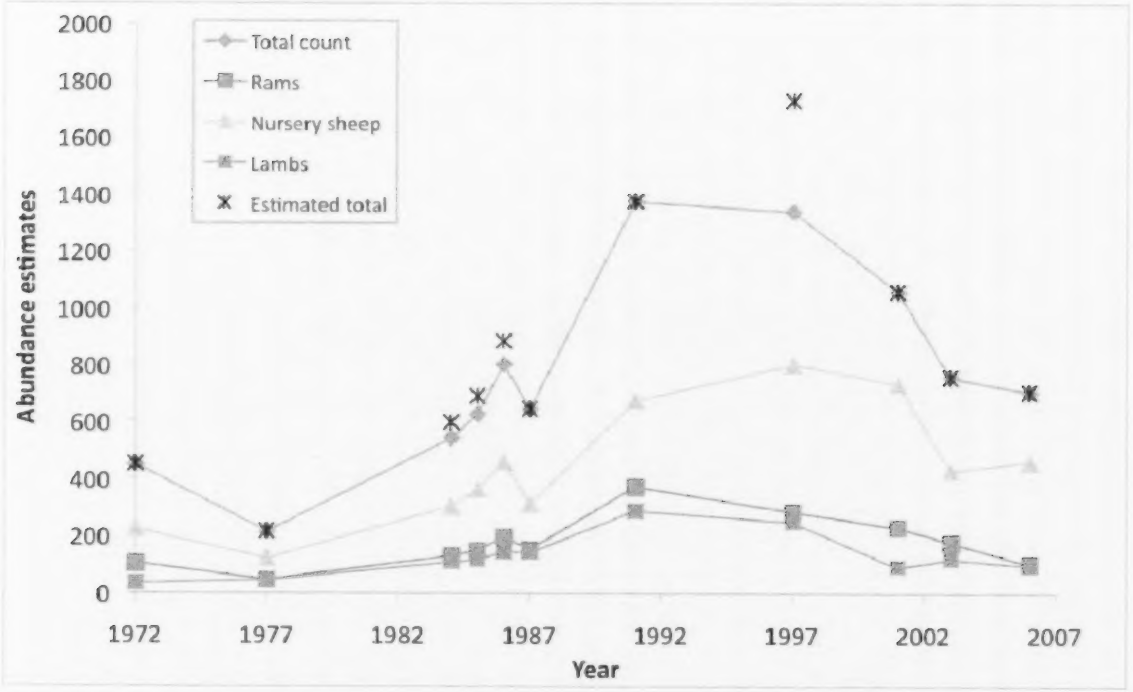

Figure 5. Raw counts and estimated Dall's sheep abundance in the Northern Richardson Mountains, from summer helicopter surveys conducted between 1972 and 2006. The 1987 survey reportedly covered a smaller area and may be an underestimation. The survey counts of 1984, 1985, 1986 and 1997 were adjusted to account for unseen animals and missed survey blocks (see description in text).

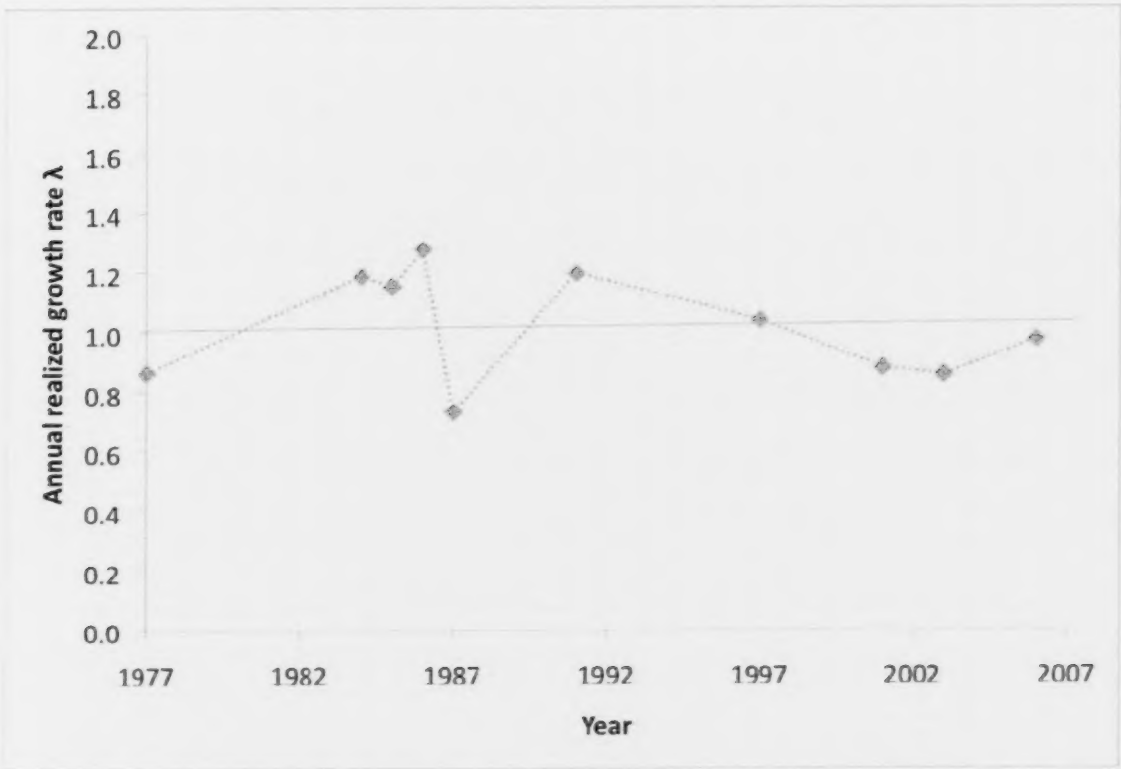

Figure 6. Estimated annual realized growth rates λ for Dall's sheep in the Northern Richardson Mountains, from population estimates of summer helicopter surveys conducted between 1972 and 2006. Each point on the x axis represents the growth rate between pairs of consecutive survey years, beginning with the rate observed between 1972 and 1977.

Note about the Observation Error and the Survey Method

The accuracy and precision of population size and composition estimates are influenced by a combination of somewhat controllable factors, such as the survey method and intensity of efforts, the experience of observers, the level of enthusiasm and attitude of the survey team and pilot; and uncontrollable factors such as weather, light conditions, and distribution of sheep into habitats where sheep are easier or harder to see (Heimer 1994). Because mountain sheep tend to live in very rugged terrain (Geist 1971, Gwich'in Elders 1997), access to their range is very limited, and ensuring that all sheep are seen and counted during the survey is a challenge. In the Northern Richardson Mountains, there has been almost no assessment of the proportion of sheep observed during the surveys, which is termed the visibility correction factor, or sightability index. Based on a double sampling method (ground and aerial count), Barichello *et al.* (1987)

recommended adding a 10% correction factor to survey estimates to account for unseen sheep. The same exercise was repeated by Stenhouse and Kutny (1987) in 2 sites, and the ground count was comparable to aerial results (difference of -2% and +5% in each case). These were the best assessments of visibility conducted so far for this population, although there is a risk that some Dall's sheep were missed by both ground and aerial crews. Based on a general evaluation of the survey, Males (1980) also inflated his fixed-wing estimate by 25%. In fact, failure to include a visibility correction factor may underestimate the number of animals present in the mountains, and prevent the use of variance and related confidence intervals when estimating population size (Bodie *et al.* 1995). Under a designed assessment of the sightability index, the aerial relocation of collared mountain sheep (Bodie *et al.* 1995) and goats (Poole 2007) both yielded about 60% visibility; so a 10% or 25% correction factor may not suffice to account for the number of sheep missed during the survey. The estimation and use of a visibility correction factor during each survey would increase the precision of population estimates and variances in the future. Not including such a correction factor, as it is currently done, may yield conservative population estimates. Conservative estimates are however preferable to overly inflated estimates and may minimize the risk of over-exploitation of this population. Moreover, there is a need to adopt a consistent approach between surveys to enable results comparison.

Another important consideration when designing a population survey is the choice between aerial or ground technique. Aerial surveys tend to inflict a higher level of stress to the population, despite being of relatively short duration. Mountain sheep have been observed to respond dramatically to helicopter or low fixed-wing overflights, and consequences of aerial disturbances may include high energy expenditures, reduced feeding, habitat shift, and potential abandonment of certain areas (Bleich *et al.* 1994, Frid 2003). The degree of response to the aircraft may however be reduced with increasing flying altitude (Krausman and Hervert 1983, who recommended survey aircraft staying at least 100m over the animals). For the survey staff, there is also a considerable risk involved in flying over the mountains, which needs to be considered by wildlife managers (Heimer 1994).

On the other hand, ground techniques, which include foot-based observations aided by a spotting scope or binoculars, are generally cheaper and cause fewer disturbances than aerial surveys. Humans can be seen as predators and elicit vigilance behaviour, or even escape behaviour (Frid and Dill 2002), but probably to a lesser extent than aerial disturbances. Ground surveys may yield a more accurate population structure, as

they allow the observers to get closer to the sheep groups and distinguish the sex and age classes more accurately. They also have the potential to involve community members into population monitoring and research. Ground surveys are, however, more laborious, of longer duration, and are also limited in their ability to count simultaneously all the sheep groups and cover a large area. This downside could be partially overcome if multiple teams were deployed, although many people on the sheep range could then become disruptive. Other than the snowmobile count reported in 1984 (Latour 1984*a*), there have been no extensive ground surveys of Dall's sheep in the Northern Richardson Mountains. In 1985, Barichello *et al.* (1987) compared results from a simultaneous ground count and an aerial survey for 2 specific areas, and found a minimal difference between the 2 (i.e. 180 sheep were observed on the ground, and 176 from the air). Ground surveys have also been conducted regularly to estimate the Dall's sheep population in the Mackenzie Mountains (A. Veitch, Environment and Natural Resources, Government of the Northwest Territories, personal communication).

For this Dall's sheep population, a combination of aerial and ground surveys might be cost-effective and enable more quickly to detect changes in population structure. For instance, if the actual frequency of helicopter surveys is maintained (~ every 3 years), annual ground surveys could help detect population trends in specific blocks, and gather demographic data such as population composition. The yearling to ewe ratio, particularly, may be a good predictor of population growth and can be assessed before or after the lambing season, which would reduce disturbance to the sheep (Dehn 1997). The combination of ground counts and aerial survey has been proposed in the recommended draft management plan for this population and should be implemented in collaboration with the communities (Element 2; Actions 3 and 4).

Knowledge Gaps:

- For most surveys conducted so far, neither the observation error nor the visibility correction factor was assessed. Such indices would increase the accuracy and provide confidence limits to the population estimates.
- Annual variations in population size and composition are not available and could help to detect population trends (increase or decline) more promptly. A combination of ground and aerial surveys could yield such information in a cost-effective way, but would need to be designed properly to optimize data quality and minimize disturbance to Dall's sheep.

Productivity

Lamb to Nursery Sheep Ratio

The recruitment of individuals, through the production and survival of lambs, is a key contribution to population growth. Even when adult sheep have relatively stable survival rates, survival rates of younger individuals can be highly variable. Low lamb production or high mortality rates for lambs and yearlings can be sufficient to trigger a population decline (Gaillard *et al.* 1998). There is insufficient knowledge of lamb births and deaths to accurately quantify this population's productivity. However, the number of lambs per 100 nursery sheep, observed shortly after lambing season, can provide a useful indicator of lamb production. This index does not consider still-births, perinatal mortality, deaths occurring before the conduction of the survey, or, for the June surveys, late births. Because lambs suffer higher mortality rates in their first few weeks of life (Simmons *et al.* 1984, Nichols and Bunnell 1999), the timing of the survey is crucial to the estimation of the lamb-to-ewe ratio.

In the Northern Richardson Mountains, the number of lambs to 100 nursery sheep ratio was determined from the population composition data reported in the periodic aerial survey estimates (Tables 1 and 2). Between 1972 and 2006, there were, on average, 32 lambs per 100 nursery sheep observed in the population, with a range between 13 and 46, and a standard error of 11 (Figure 7). The counts were, however, done at various times of the year (as indicated in Figure 7), and it is likely that counts done in July or later were lower than if they had been done in June or late May because of the relatively high early mortality (Simmons *et al.* 1984). In general, for thinhorn sheep populations, the production of lambs has been inversely associated with population density, severe winter weather, and heavy snow falls (Murphy and Whitten 1976, Nichols 1978*a*). The number of lambs born, particularly during colder years, is affected by the density of sheep that were present in the previous year (Geist 1971, Forchhammer *et al.* 2001 for Soay sheep). There is strong evidence that large scale weather phenomenon known as the Pacific Decadal Oscillation (PDO) is the driving force behind fluctuations in lamb production (Loehr 2006). The combination of these factors and the influence of other limiting factors are discussed in Section 2.3.

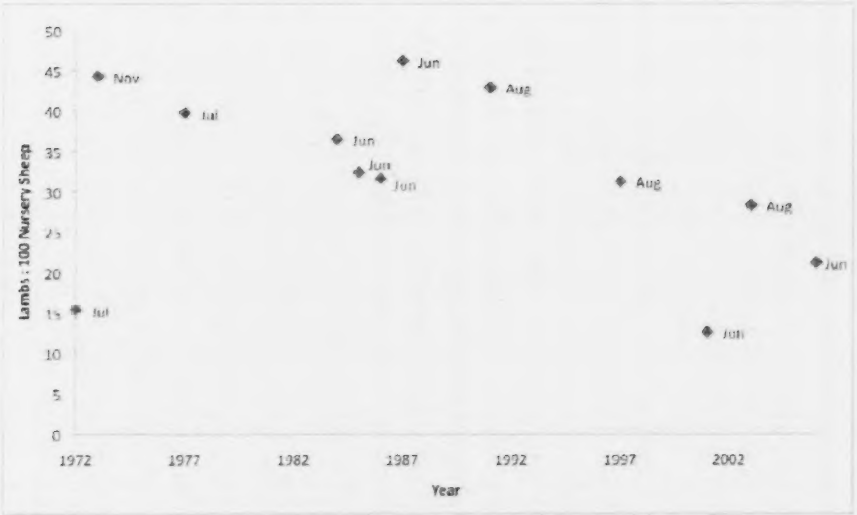

Figure 7. Lamb to 100 nursery sheep ratio, as estimated from aerial surveys (including composition counts) performed between 1972 and 2006 in the Northern Richardson Mountains. When multiple counts were conducted the same year, only the one nearest to the post-lambing period was selected. As such, ratios of March 1973 and September 1977 were not included in this graph.

Timing of the Lambing Season

Lambing season for this population is estimated to peak around the third and fourth weeks of May, but it has been observed to start as early as May 5 and end as late as June 15 (Nolan and Kelsall 1977, Barichello *et al.* 1987). Assuming the lambing period is regulated by similar processes as that of other populations in the southwest Yukon, its onset and duration are believed to be related to photoperiod and energy constraints, with a shorter duration occurring in environments of lower plant productivity (Bunnell 1980, Nichols and Bunnell 1999).

To increase the precision and accuracy of productivity estimates, it is recommended to survey the population at the same time period each year. Surveys conducted immediately after the lambing season are appropriately used to evaluate the annual lamb production, while surveys conducted before the lambing season are best to evaluate lamb survival and provide an indicator of recruitment (the number of lambs who have survived to their first year of life and who will join the pool of breeding individuals). Recruitment can also be estimated in post-lambing surveys by counting the number of yearlings still alive, but differentiating between yearlings and adult ewes becomes increasingly challenging as time goes by. This distinction is more easily done by ground observation (i.e. with a spotting scope) than from an aircraft.

Age at First Reproduction

In the Northern Richardson Mountains, Gwich'in Elders (1997) have mentioned that ewes can first give birth to a lamb when they are between 2 and 4 years of age. In general, yearlings of 18 months of both sexes (or even younger with supplemental feeding (Hoefs and Nowlan 1993)) may be physiologically ready to reproduce, although only a small proportion of ewes may actually breed at that age. Most adult ewes (older than 2 years) should be able to engage in reproduction. Research in Alaska reported a 100% pregnancy rate for adult ewes (2 years and older), and 75% for yearlings (Nichols 1978*a*). A much lower proportion will actually give birth to a lamb that will survive the first few weeks of life, which is reflected in the lower values of lamb-to-nursery sheep ratios (Nichols 1978a). In the Mackenzie Mountains (NT), 78% (N = 94) of adult ewes were pregnant, and less than half (3 of 7) of the 18-month-old yearlings were pregnant (Simmons *et al.* 1984). Ewes were reported to produce lambs until 16 years of age, although no lambs were seen with ewes older than that (the oldest ewe recorded was 19 years of age, as described by Nichols, 1978). Twin births are very rare for thinhorn sheep and most ewes give birth to a single lamb (Nichols 1978*a*, Nichols and Bunnell 1999).

Rams usually have to wait a few more years (around 7 years of age) before being able to participate in the rut because of behavioural constraints imposed by older rams (Geist 1971, Nichols 1978*b*, Nichols and Bunnell 1999). In the Richardson Mountains, Barichello *et al.* (1987) reported that all 5-year-and-older rams were accompanied by ewes during the 1985 rut, and observed one 4-year-old ram courting a ewe. These observations were made when the population was low and increasing. Generally, the capacity of ewes and rams to participate in reproduction activities depends on how much energy reserves they were able to store during the previous summer (Nichols 1978*a*)

Knowledge Gaps:

- The accuracy of productivity estimates for this population is impaired by irregularity of survey timing. A more consistent timing of the surveys would increase the quality of the estimates and facilitate their comparison between years.
- Little is known about the age at first reproduction of either ewes or rams in this population.

2.3. Limiting factors

Although we do not know the causes of mortality for Dall's sheep in the Northern Richardson Mountains, it seems reasonable to assume that the fluctuations in this population are related to a combination of factors, which can vary from year to year. As for other mountain sheep populations, the factors that can limit or regulate population growth generally fall into one of the following categories: weather and snow conditions, density dependence, competition with other species, predation, diseases and parasites, and harvest. The following sections describe how each of these factors may have a limiting effect on this population, based on knowledge acquired about this and other mountain sheep populations. Additionally, accidental falls and research-related mortality can cause occasional deaths and are discussed at the end of this section.

Weather and Snow Conditions

Environmental conditions can have a strong impact on thinhorn sheep survival and productivity. Being located at the northern edge of the species range, Dall's sheep in the Northern Richardson Mountains are limited by a shorter plant growth season and exposed to more severe winter conditions than most other populations. Prolonged periods of extremely cold temperatures consume large reserves of energy from the sheep, and therefore result in higher mortality and lower birth rates (Burles and Hoefs 1984). Cold summers are associated with brief periods of vegetation growth, and the sheep may not be able to accumulate enough fat in such years to cope with the coming winter. On the other hand, warmer summers can be associated with increased plant productivity, which will often result in higher Dall's sheep survival and productivity rates. Higher levels of spring and summer precipitation have been shown to improve neonatal survival for bighorn sheep (Portier *et al.* 1998). The snow layer on the ground can also affect the sheep in the winter, as more snow may translate to more energy spent to escape from predators and a reduced food intake (Murphy and Whitten 1976, Chappel and Hudson 1978, Goodson *et al.* 1991). Moreover, the horn growth of Dall's sheep rams has been linked to cyclic climate and precipitation patterns in the southern Yukon; warmer years were associated with greater horn growth (Hik and Carey 2000).

The weather station closest to the Northern Richardson Mountains is in Aklavik, NT (Environment Canada), and has recorded temperatures, snow and rain precipitation since 1926 (data missing 1960 to 1991). Between 1928 and 2006[3], the average temperatures in January and July were –27.8°C and 13.6°C respectively; and the average annual precipitation was 236 mm. with

[3] Only years with 12 months of data were included ($N = 40$). Data accessed online at: http://www.climate.weatheroffice.ec.gc.ca, on June 1, 2009.

snow comprising about half of the total. Additional weather stations are located in Fort McPherson and Inuvik, NT. To gain further insights into the climatic conditions prevailing in the sheep range itself, and to relate the weather to Dall's sheep movements and habitat use, the Gwich'in Renewable Resources Board installed a weather monitoring station on top of Black Mountain in 2006. The station, however, malfunctioned shortly after deployment. Also, to assess the influence of snow depth on the movements and habitat use of Dall's sheep and wolves (a potential predator) snow surveys were also conducted during winters 2007 and 2008 by monitors from the communities of Aklavik and Fort McPherson. A total of 109 sites were surveyed and will serve to create a spatial data layer of estimated snow depth in the study area, which will be incorporated into the analysis of habitat use through the use of a GIS software (C. Lambert Koizumi, in preparation).

Density Dependence

The carrying capacity is the population size of a species that a given area can sustain over the long term, given the food, habitat, water, and other necessities available in the environment. When the carrying capacity of the land is reached, resources or space become limited and animals are forced to survive on less and thus become more vulnerable to other limiting factors. For Dall's sheep, the carrying capacity of a habitat has been related to the capacity of the winter range to sustain a certain density of population (Nichols and Bunnell 1999). The effect of density dependence on mountain sheep populations has been documented in earlier studies (Murie 1944, Geist 1971), and recent investigations have continued to confirm its important role in population regulation. Bighorn sheep in the Canadian Rockies, particularly lambs, were found to have lower survival rates when the population was at high densities (Portier *et al.* 1998). For Soay sheep (*Ovis aries*) in Scotland, density dependence was identified as one major contributor to population growth, in combination with climate (Milner *et al.* 1999, Coulson *et al.* 2001, Forchhammer *et al.* 2001, Coulson *et al.* 2008). In general, high sheep density will make lambs and juveniles more sensitive to harsh environmental conditions (Portier *et al.* 1998, Forchhammer *et al.* 2001). A decline in the sheep population will usually reduce grazing intensity on the land and allow the vegetation to grow back.

Using the available data, the lamb to nursery sheep ratios showed little correlation to the population abundance estimates for the same year (correlation coefficient $r = -0.15$) or for the previous survey ($r = 0.415$). To be able to relate spring lamb production to the previous year density, annual counts are necessary. Dall's sheep population surveys in the Northern Richardson Mountains have not been conducted annually, making conclusions based on an evaluation

of the effect of density dependence on the following year's lamb production tenuous.

Interspecific Competition

Similar to density-dependent mechanisms related to intraspecific competition (competition interactions within a species), competition with other species (interspecific) could result in lower population productivity and reduced survival. The influence of interspecific competition on thinhorn sheep has not been often investigated, but has been regarded as minimal because few other species occur on sheep wintering habitat (Nichols and Bunnell 1999). Potential competition interactions have, however, been suggested between mountain sheep and goats (*Oreamnos americanus*), barren-ground caribou (*Rangifer tarandus groenlandicus*), bison (*Bison bison*), marmots (*Marmota sp.*), ground squirrels (*Spermophilus parryii*), and free-ranging domestic horses and feral ass (*Equus sp.*) (Hoefs and Brink 1978, Nichols and Bunnell 1999, Marshal *et al.* 2008).

In the Northern Richardson Mountains, muskox (*Ovibus moschatus*), the Porcupine herd of barren-ground caribou, and moose (*Alces alces*) are the other ungulates sharing the land with Dall's sheep, and may compete with them through resource exploitation or direct interference. Ground squirrels and snowshoe hare (*Lepus americanus*) can also be found throughout the sheep range and could contribute to interspecific competition with sheep by reducing plant biomass during the summer season.

The Porcupine caribou herd is a large herd that migrates across northern Alaska, the Yukon, and the northwest limit of the Northwest Territories. Based on aerial surveys, the population was estimated at 123,000 in 2001, and is believed to currently number between 90,000 and 100,000 animals (Porcupine Caribou Management Board website[4]). The Richardson Mountains are located at the eastern limit of the herd's range, and groups of caribou can be seen in the area throughout most of the year, with higher densities during the spring and fall migrations (Russell and McNeil 2002). Caribou diet is similar to that of sheep and muskox (which are mostly grazers), and composed mainly of lichens and mosses during the winter, with an increase in vascular vegetation during the spring and summer (including cottongrass, willows, dwarf birch, forbs) (Thompson and McCourt 1981).

Moose, in contrast, do not migrate and are mostly browsers. Moose are usually found in the valleys and the lower slopes, where

[4] Accessed at: http://www.taiga.net/pcmb/population.html, on April 6, 2010.

they can find a higher abundance of willows (*Salix* spp.), one of their main food sources, especially in the winter (Risenhoover 1989). The moose density in the Richardson Mountains was estimated at 4.8 / 100 km^2 in 2000 (D. Cooley, Environment Yukon, unpublished), and at 3.78 / 100 km^2 in 2006 (Lambert Koizumi 2006).

After being extirpated from Alaska in the late 1800s, a small group of muskox were reintroduced in 1969–1970, and have since expanded their range eastward into the Yukon North Slope and adjacent areas (Reynolds 1998). Muskox are now sharing the habitat occupied by this sheep population in the Northern Richardson Mountains, and have been located several times in close proximity to Dall's sheep groups. When Barichello and colleagues worked in the area, only 1 muskox was observed in 1984 (Barichello et al. 1987). A group of 46 muskox was observed in 2003 in the Goodenough survey block (Nagy et al. 2006a); 52 muskox were reported during a moose survey in March 2006 (Lambert Koizumi 2006); and 98 were counted during the 2006 Dall's sheep survey, also in the same area (Davison and Cooley 2006; but the group may have been double-counted (D. Cooley, Environment Yukon, personal communication). The effect of muskox on this Dall's sheep population has not been investigated, although Gwich'in elders and harvesters of Aklavik, Fort McPherson, and Inuvik have reported concerns of potential negative interactions between them (Shaw et al. 2005).

Predation

Dall's sheep must be constantly vigilant to avoid predators. Escape to rugged areas is their main defence mechanism. Interviews with elders and active land users in Aklavik, Fort McPherson and Inuvik in 2000 and 2001 indicated that Dall's sheep may be prey to wolves, grizzly bears, wolverines (*Gulo gulo*), black bears (*U. americanus*), golden eagles (*Aquila chrysaetus*), and potentially cougars (*Puma concolor*), who are believed to occasionally transit through the area (Shaw *et al.* 2005). Foxes (*Vulpes vulpes*) and lynx (*Lynx canadensis*) are also present and could occasionally prey on weak individuals or newborn lambs.

Barichello *et al.* (1987) found that 1 to 3 of the 4 ram mortalities recorded during monitoring of 12 collared sheep were likely caused by wolves. Research done in the 1990s indicated that wolves in the Northern Richardson Mountains and on the Yukon North Slope prey primarily on moose (*Alces alces*), and seasonally on the herd of Porcupine caribou crossing the area (Hayes *et al.* 1997, Hayes and Russell 1998, Hayes *et al.* 2000). However, in other areas it has been

shown that wolf packs can significantly limit mountain sheep populations (Nichols 1978b, Sawyer *et al.* 2002). Research in Kluane and Denali National Parks demonstrated that predation can cause significant Dall's sheep mortality (Murie 1944, Sumanik 1987, Mech *et al.* 2003). Moreover, recent declines of Cape Bathurst and Bluenose-West barren-ground caribou herds in the adjacent Northwest Territories, as revealed by photo-censuses of the herds (Nagy and Johnson 2006), combined with a decline in the Porcupine caribou herd (Porcupine Caribou Management Board 2007, Fisher *et al.* 2008) could mean that alternate prey, such as Dall's sheep, will suffer from higher predation rates because of lower caribou availability (i.e. prey switching (Dale *et al.* 1994)). At present, there is subsistence harvesting of wolves in the area, with no management plan for wolves in place.

Grizzly bears are common in the Northern Richardson Mountains, and information from traditional knowledge, aerial surveys (Nagy *et al.* 2006*a*, Nagy *et al.* 2006*b*), and preliminary data (C. Lambert Koizumi, unpublished) indicate an overlap of the ranges of grizzly bears and Dall's sheep. During the 2001 surveys, most grizzly bears were observed along the continental divide (the Yukon-Northwest Territories border), with some individuals in the eastern part of the range (Nagy *et al.* 2006*b*). In 2003, dens were observed along the continental divide, but most grizzly bears were observed along the eastern limit of the range, in the Black Mountain and surrounding areas (Nagy *et al.* 2006*a*). Research in Alaska identified grizzly bears as the main predator of moose and caribou calves (Ballard and Miller 1990, Adams *et al.* 1995), and their potential as an ungulate predator seems to be higher when the ungulates are only few weeks old (Zager and Beecham 2006). On the Northwest Territories side, grizzly bear harvest is restricted to subsistence users and is regulated by a management agreement in the Gwich'in Settlement Area and quotas in the Inuvialuit Settlement Region. On the Yukon side, in addition to aboriginal subsistence harvest, resident hunters may harvest 1 grizzly bear every 3 years during the spring and fall hunting seasons (2009–2010 Hunting regulations summary booklet, Yukon Government, Department of Environment[5]). Since 1980, there has been only 1 grizzly bear killed by a licensed Yukon resident hunter in the Northern Richardson Mountains (Yukon Government, unpublished data).

Golden eagles can also prey on Dall's sheep lambs, particularly during the first few days of life. Numerous attacks on lambs were recorded in the southern Yukon during an observation study (Barichello *et al.* 1991), although only 1 successful case of predation was observed. Ewes are highly

[5] Accessed online at: http://www.environmentyukon.gov.yk.ca/huntingtrapping/documents/ hunting_regs_0910web.pdf, on September 25, 2009.

protective of their lambs. Golden eagles are known to nest on the cliffs of the Richardson Mountains in the summer, and predation on neonates is believed to occur (Gwich'in Elders 1997, Shaw *et al.* 2005). The 2001 and 2003 aerial surveys reported observations of golden eagles throughout the range (Nagy *et al.* 2006*a*, Nagy *et al.* 2006*b*).

Because of the remoteness of this mountain range and the lack of an easy access, characterizing predation events and following the fates of a large number of Dall's sheep would require intense monitoring and necessitate considerable financial and human resources. However, the investigation of indirect effects of predation is more easily done and may reveal important patterns and mechanisms underlying predator-prey interactions. Indirect, or non-consumptive, effects on prey species include vigilance behaviour, reduced feeding, altered activity budget, and habitat shift (Schmitz et al. 2004). These indirect effects are ubiquitous and can be determinants in shaping the spatial dynamics and behaviour of prey (Abrams 2008, Altendorf et al. 2001, Corti and Shackleton 2002, Peckarsky et al. 2008), who need to balance foraging needs and predation risk. Predators then respond to the prey behaviour and spatial distribution (Iwasa *et al.* 1981, Lima 2002).

In 2006, a 3-year study was launched to assess these indirect effects of wolves and grizzly bears on Dall's sheep in the Northern Richardson Mountains (Gwich'in Renewable Resources Board and University of Alberta, C. Lambert Koizumi *et al.*, in preparation). The study focused on spatial interactions between the 3 species and their habitat use, on the wolves and the grizzly bears' diet, and on Dall's sheep vigilance behaviour during lambing season. Individuals from the 3 species (6 Dall's sheep ewes, 9 wolves, and 15 grizzly bears) were equipped with GPS satellite collars in 2006 and 2007. The last collars released in the fall 2009, and results from this study are now being analyzed. A study of similar design found the predation risk by grizzly bears and wolves to be one of the important variables explaining Dall's sheep habitat selection in northern British Columbia (Walker *et al.* 2007).

Parasites and diseases

Neither parasites nor diseases have been documented as a primary factor in controlling thinhorn sheep populations (Nichols and Bunnell 1999). Elders and harvesters have characterized Dall's sheep in the Northern Richardson Mountains as generally healthy, and very few parasites or diseases have been reported (Shaw *et al.* 2005). Domestic sheep or goats are generally not present on the range of thinhorn sheep, and they have not been subject to epizootic pneumonia like the bighorn sheep (George *et al.* 2008, Schommer and Woolever

2008). Dall's sheep can nevertheless carry a variety of disease agents. Gastrointestinal parasites are common but are not generally in high enough loads to impair digestive function. These parasites can be detected by examining the feces of the sheep, or by conducting a necropsy. Other common parasites include few species of lungworms and other nematodes as well as various protozoa (see Bowyer and Leslie 1992). Common diseases include viral or bacterial infections such as arboviruses, contagious echthyma virus, brucellosis, parainfluenza virus, rickettsia, epizootic hemorrhagic disease, chronic pneumonia, and necrosis of the horn cores. Also quite common is mandibular osteomyelitis (lumpy jaw) (Murie 1944), and approximately 23% of a large sample of Dall's sheep skulls (N = 1,481) from across the species range were found to be affected (Hoefs 2001). To our knowledge, this condition has not been reported for Dall's sheep in the Richardson Mountains. Mandibular osteomyelitis can lead to distorted jaw and tooth infections, but has not been related to direct mortality of affected individuals although they may become more prone to starvation or predation (Murie 1944, Bunch *et al.* 1999).

The emergence of new parasites in Dall's sheep range could become more common in the future, as global climate warming continues (Kutz *et al.* 2004, Jenkins 2005). For 12 of the 13 rams captured in the 1980s, fecal analysis identified the presence of larvae of undetermined species of the genus *Protostrongylus* (Barichello *et al.* 1987). More recently, 2 species of lungworms (protostrongylids: *Parelaphostrongylus odocoilei* and *Protostrongylus stilesi*) were detected in Dall's sheep of the Mackenzie Mountains (Kutz *et al.* 2001), which led to more lungworm research in the population of the Northern Richardson Mountains. Three sheep harvested on Black Mountain were confirmed hosts of *P. stilesi* (Hoberg *et al.* 2002). The same parasite was also detected in 2 adult muskox on the Yukon North Slope (Hoberg *et al.* 2002). *P. stilesi* can switch between the 2 hosts, and the overlap between muskox and Dall's sheep could be the cause of the infection in the muskox population (Dall's sheep are the typical host and are believed to be the original carrier of this lungworm (Hoberg *et al.* 2002)). On the other hand, *Umingmakstrongylus pallikuukensis*, a lungworm affecting muskox, could not switch to a Dall's sheep host under experimental conditions (Kutz *et al.* 2004). No occurrence of *P. odocoilei* has been reported for Dall's sheep in the Richardson Mountains (Jenkins 2005) but based on experimental infection trials, this parasite could lead to respiratory distress and increase chances of mortality (Jenkins *et al.* 2005). The effect of these parasites on the Northern Richardson population is unclear, and the massive die-offs observed in bighorn sheep populations (Bunch *et al.* 1999) have not been observed for Dall's sheep.

Harvest

Mountain sheep are sensitive to harvest, and this Dall's sheep population is no exception. What is known of harvest levels and a discussion on the impact of hunting in the Northern Richardson Mountains can be found in Section 4.

Other Mortality Factors

Dall's sheep are extremely agile and can admirably handle steep cliffs and rocky slopes. However, under certain icy conditions or as a result of avalanches, some individuals may lose their balance and die from an abrupt fall. Accidental falls are not believed to be very common, although some elders and harvesters have indicated observing such mortality events (Gwich'in Elders 1997). During the retrieval of radio-collars in 2005 and 2006, 3 sheep carcasses were found at the bottom of a steep canyon (C. Lambert Koizumi, personal observation). While other factors could have been the cause, accidental fall appeared to be a likely reason for the deaths of these individuals. According to Nichols and Bunnell (1999), animals in poor body condition (as indicated by a low fat content in their bone marrow) are more susceptible to accidental falls, as were rams that are inattentive during the rut (i.e. during ram clash).

Moreover, there have been numerous concerns expressed about the effects of research on Dall's sheep in the Northern Richardson Mountains, particularly from people living in Fort McPherson (C. Lambert Koizumi, personal observation from attendance at community meetings). Some elders have claimed that sheep die as a result of being captured or collared. Although the scientific community may minimize the impact of research activities, the effect of handling and collaring on sheep should not be understated. Capture has the potential to cause injuries, produce excessive stress, and lead to capture myopathy. Capture myopathy is a syndrome that can appear from several hours to 2 weeks after capture, and includes symptoms such as hyperthermia, renal failure, shock, muscle diseases, and sudden death (Bunch *et al.* 1999). Capture myopathy can be prevented by reducing the chase time, the handling time, and ensuring that few and only experienced people participate in the capture and handling. Other problems to consider are neck lesions and higher energy expenditures related to the wearing of a collar. Krausman *et al.* (2004) observed a high rate of neck lesions for bighorn sheep fitted with collars equipped with GPS and satellite technology, in contrast to the smaller VHF-only collars. Such lesions could be detrimental to the body condition, reproductive success, or even survival of the

collared individuals. Continued improvement of radio collar equipment is needed so that smaller transmitters can yield the same amount and quality of information. Before starting research on this population, careful consideration should be given to the study question, experimental design, and selected methods. As much as possible, methods with less impact or disturbance should be chosen.

Knowledge Gaps:

- It is currently unclear what the driving factors for this population are. In particular, knowledge is limited on:
  - the influence of weather on the abundance and fluctuations of this population;
  - the importance of density dependence as well as competition interactions (habitat overlap and resource partitioning) with other species, particularly muskox;
  - numbers of predators in the Northern Richardson Mountains, and what the quantifiable effects of wolves, grizzly bears, golden eagles, and other predators may be on this population;
  - emerging diseases and parasites in this population; and
  - impacts of research on this population.

3.0. Habitat

3.1. Description

The Northern Richardson Mountains are located above the Arctic Circle (67o30' – 68o30' N, 135o30' – 137o W) and are part of the British-Richardson Mountains ecoregion, in the Taiga Cordillera ecozone (Scudder 1997). The mountains in this ecoregion are largely unglaciated, resulting in steep, V-shaped valleys at higher elevations and more gentle lower slopes along the broader valleys. The mountains range between 400 and 1200 m, with the highest peaks in the centre of the range, at the border between the Northwest Territories and Yukon (i.e. the Continental Divide). The Northern Richardson Mountains are bordered on the south by the Peel River Plateau, on the east by the Mackenzie Delta, on the north by the Yukon Coastal Plain (which ends in the Beaufort Sea), and on the west by the British Mountains and Old Crow Flats. Major rivers flowing through the range are the Bell River, Rat River, Fish Creek, Sheep Creek, and Willow River.

The vegetation of the Northern Richardson Mountains is dominated by alpine tundra, and treeline is

located at approximately 300 m above sea level (Smith *et al.* 2004). Tree species, mostly black spruce (*Picea mariana*) and balsam poplar (*Populus balsamifera*), occur only in protected valleys with favourable exposure (Barichello *et al.* 1987). As discussed in Section 2.1, most of the Richardson Mountains remained unglaciated during the Pleistocene, except for the eastern flanks of the range. The passage of the glaciers mostly affected the eastern valley bottoms, while the ridges and slopes stayed mainly free of ice. Repercussions of glaciations are evident in the plant communities today, with slopes dominated by lichens and forbs, and drift valley bottoms covered in moss, grass, and sedge communities (Smith *et al.* 2004). Typical plants of the Northern Richardson Mountains include cottongrass and other sedges (*Eriophorum spp., Carex spp.*), mountain avens (*Dryas spp.*), alpine bearberry (*Arctostaphylos alpina*), willows (*Salix spp.*), dwarf birch (*Betula glandulosa*), saxifrages (*Saxifraga spp.*), Arctic white heather (*Cassiope tetragona*), black crowberry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorus*), blueberries (*Vaccinium spp.*), moss campion (*Silene acaulis*), peat moss (*Sphagnum* spp.), and diverse lichens (Cladonia spp., Cladina spp., Stereocaulon pascale, etc.) (Scudder 1997 and authors' personal observations). Higher peaks and steep slopes are mostly rocky and non-vegetated. The entire range is mainly composed of sedimentary rock (Smith et al. 2004), and underlaid by permafrost (Scudder 1997).

The area inhabited by Dall's sheep covers approximately 4,000 km2 (derived from the area encompassed by the 12 survey blocks), although only about 50% of the range appears suitable for Dall's sheep (locations above treeline providing adequate access to pasture and escape terrain) (Barichello et al. 1987).

3.2. Dall's sheep Habitat Use

Both Traditional Knowledge and scientific studies have confirmed that Dall's sheep in the Northern Richardson Mountains move between various habitats during the year, depending on the available forage and on their reproductive status (Barichello *et al.* 1987, Gwich'in Elders 1997). During winter, thinhorn sheep generally remain at higher elevation, and in proximity to rugged areas that act as escape terrain – taking advantage of wind-blown areas, which facilitate locomotion and food access, and minimize predation risk (Geist 1971, Nichols and Bunnell 1999). During the spring, they venture to lower elevations, to take advantage of nutritious newly emergent vegetation and to drink from the creeks (Gwich'in Elders 1997). As the snow melts, pregnant ewes will then seek a safe ground to give birth, usually in proximity to escape terrain (or right on a steep cliff), and rejoin the other ewes a few days after their lambs are born. Lambing

areas have been identified around Black Mountain, Mount Lang, Sheep Creek, Summit Lake, Fish Creek headwaters, Bear Creek, Scho Creek, and Bell River (Barichello *et al.* 1987). The ewe and lamb pairs, along with yearlings and barren ewes then form nursery groups, and stay together for most of the summer, usually in proximity to escape terrain (Rachlow and Bowyer 1998). The groups of rams, being less susceptible to predation, tend to go further away from escape terrain and benefit from higher quality of forage. During the rut, in late fall, bands of rams and nursery sheep congregate close to the winter range, where they will stay for the following months. In late fall, the sheep who ventured to the western portion of the Richardson Mountains during the summer seem to return to the Black Mountain area (Simmons 1973).

In the early 1980s, 12 rams were fitted with VHF collars in the Northern Richardson Mountains and relocated on a monthly basis (Barichello *et al.* 1987, Barichello and Carey 1989). As with most other populations, the winter range of Dall's sheep in the Northern Richardson Mountains was constricted compared to the habitat used in other seasons, and Dall's sheep seemed to move less extensively during the winter season (total home range size between 10 and 50 km^2, with a winter home range between 3 and 26 km^2) (Barichello *et al.* 1987). Longer movements were recorded in June and October, and on an annual basis, rams appeared to be faithful to summer and winter ranges (Barichello and Carey 1989).

Because of the limited information yielded by VHF collars, a habitat selection study was started in 2004 and 2005 by the Gwich'in Renewable Resources Board (D. Auriat, unpublished), in collaboration with the Government of the Northwest Territories. Eight rams were equipped with GPS satellite collars, and their location was recorded every 4 hours. Random and used sites were sampled for vegetation and characterized during the summers 2004 and 2005, with the intent of analyzing fine-scale habitat selection of this population. Results have yet to be made available, but the ram locations will likely be integrated with the location data of the 6 ewes collared in 2006 and provide a basis to evaluate habitat use for rams and ewes in this population. Based on preliminary data, Dall's sheep tend to be found at higher elevations, and on steep slopes with south oriented aspects (C. Lambert Koizumi, unpublished). This is similar to Stone's sheep in northern British Columbia, a population whose habitat selection further appears to be influenced by wolf and grizzly bear predation risk (Walker *et al.* 2006, Walker *et al.* 2007).

To assess the productivity of this range and verify if the sheep could be limited by density-dependence or competition with other ungulates, 4 exclosures were installed in the Northern Richardson

Mountains in 2004 (Gwich'in Renewable Resources Board, D. Auriat). The objective was to compare vegetation biomass and composition between grazed versus protected sites (similar to what Hoefs (1984*b*) did in Kluane National Park). The experiment was unsuccessful as the fence installations did not properly exclude ungulates (one was hit by a snowmobile; another was used as a scratching post by a herd of muskox). Little information is available regarding the productivity of this range.

3.3. Mineral Licks

Similar to other mountain sheep, minerals are vital to thinhorn sheep. Licks can be used for many years, and are believed to provide important minerals necessary for growth (particularly sodium, magnesium, and calcium lost during the winter) and, in the case of nursing ewes, lactation (Nichols and Bunnell 1999). Nursery groups in particular stay in proximity of mineral licks, especially during the spring and summer seasons (Nolan and Kelsall 1977). In the Northern Richardson Mountains, the serum analysis of 12 rams identified low levels of copper, iodine, and calcium, which could indicate deficiencies in these minerals (Barichello *et al.* 1987). In their habitat assessment, Nolan and Kelsall (1977) identified 4 lick areas in the Northern Richardson Mountains: Bear Creek headwaters, southwest of Black Mountain, Rat River Pass, and south of Sheep Creek. A mineral analysis of the licks found the presence of silicon, barium, iron, manganese, titanium, rubidium, and zirconium (trace). Traces of zinc and lead or arsenic were also found in the Bear Creek lick, and arsenic in the Rat Creek lick (Nolan and Kelsall 1977). More licks were later identified between Black Mountain and Mount Lang and east of the headwaters of Little Bell River (Barichello *et al.* 1987). Local and traditional knowledge also reported licks along the valleys of Fish Creek, on a creek south of Twin Lake, and south of Long and Ogilvie Lakes (Shaw *et al.* 2005).

3.4. Land Use, Development and Climate Change

The Richardson Mountains are an area of high traditional use by the Gwich'in, Vuntut Gwitchin, and Inuvialuit peoples. A number of Gwich'in archaeological sites exist along the main drainages, and various routes and family trails were established generations ago to travel between hunting and meeting areas (Haszard and Shaw 2000). Today, the Richardson Mountains are still widely used by the Gwich'in from Fort McPherson and Aklavik, the Vuntut Gwitchin from Old Crow, and the Inuvialuit from Aklavik and Inuvik, and is considered a prime area for hunting large mammals such as caribou, moose, Dall's sheep, and grizzly bears. The Richardson Mountains fulfill the

subsistence and recreational needs of many northern peoples.

A portion of the Northern Richardson Mountains in the Gwich'in Settlement Area was classified as a special management zone for *Vàdzaih* (Porcupine caribou); and the *Ddhah zhit han, Eneekaii han, Chii gwaazraii* (Rat River, Husky Channel, and Black Mountain area) form a conservation zone to protect wildlife, land, and traditional uses in these areas (Gwich'in Land Use Planning Board 2003). The potential for sport hunting (i.e. hunting by non-beneficiaries) in the Northwest Territories, particularly for Dall's sheep, has been recognized and could be implemented if local organizations are supportive (Gwich'in Land Use Planning Board 2003). On the Yukon side of the Northern Richardson Mountains, west of the *Ddhah zhit han, Eneekaii han, Chii gwaazraii* conservation zone, the Summit Lake – Bell River area was designated as a protected area and the adjacent land is currently part of the North Yukon Land Withdrawal. As such, it is not available for mineral or oil and gas disposition or exploration (North Yukon Planning Commission 2009). In the Inuvialuit Settlement Region, the area is also subject to the Aklavik Community Conservation Plan (Wildlife Management Advisory Council (NWT) 2000). In this plan, the portion of this Dall's sheep population within the Inuvialuit Settlement Region is contained in a special subregion that is managed to eliminate damage and disruption as much as possible. This Aklavik subregion, *725D-Eastern North Slope, East of Babbage River* is also recognized to contain important habitat for thinhorn sheep, including lambing, rutting, winter range and migration corridors. Specific conservation measures in the Aklavik Community Conservation Plan include recommendations not to harvest when Dall's sheep are pregnant (November to May), to harvest sustainably and to prevent disruptive land use by identifying and protecting important sheep habitats.

Although the area is presently relatively pristine, potential oil and gas development in the adjacent Mackenzie Valley, or on the Yukon or Alaska North Slope, could leave a heavy footprint. Oil reserves and gravel deposits may be found in the Rat River watershed, although there is currently no plan for a pipeline or gravel extraction (Gwich'in Land Use Planning Board 2003). However, if the Mackenzie Gas Project goes ahead, predictions are that the Richardson Mountains would be developed within 30 years (Holroyd and Retzer 2005). Exploration surveys started in 2006 (geological field trip of Devon Canada), and more could happen in the future. As previously noted, Dall's sheep are very sensitive to sensorial disturbances, such as aerial overflights or nearby human presence, and can respond dramatically (Krausman and Hervert 1983, Bleich *et al.* 1994, Frid 2003, Loehr *et al.* 2005). The level of

response varies between populations, and depends on the perceived level of risk. If a disturbance is repeated and is not associated to a negative consequence, however, Dall's sheep could become habituated and tolerant. Based on the research done by Frid (2003), Yukon Government recommends that to mitigate the effect of flying over the sheep ranges, pilots should (1) plan the route to avoid known sheep range and sensitive areas; (2) if flying near the sheep range is necessary, keep the distance from the aircraft to the sheep greater than 3.5 km (i.e. by increasing altitude of aircraft or deviating the flight path); (3) maintain an altitude lower than the sheep, when closer than 3.5 km; (4) minimize the number of flights; (5) fly during the sheep's active period; (6) fly at an angle (not directly towards) when approaching the sheep; and (7) not hover over or circle the sheep groups (Leberge Environmental Services 2002).

Additionally, an examination of Aklavik weather data (Environment Canada[6]) reveals an increase in temperatures and in precipitation during the past few decades. Annual average temperature between 1928 and 1958 was –9.01°C and rose to –8.00°C between 1991 and 2006 (1-way t-test: $t(38) = -2.96$, $p = 0.003$). The average precipitation (rain and snow combined) also increased from 213 to 273 mm for the same 2 periods (1-way t-test: $t(38) = -2.39$, $p = 0.011$). These trends are consistent with regional and international climate analyses that have revealed warming temperatures in the Western Arctic, placing this area amongst the most affected by climate change (Walther *et al.* 2002, Parmesan 2006). A rapid warming will likely influence abundance and composition of vegetation, wildlife, and parasite agents. A longer plant growing season could mean enhanced productivity of this sheep population, although this simple relationship is complicated by a number of factors, including population fluctuations in other species (potential changes in competition and predation interactions), range shift in others (e.g. appearance of cougars), as well as the spread of new diseases and parasites (Kutz *et al.* 2004). The Richardson Mountains are likely to undergo significant changes in the future, and there is a need to assess the current species' status and interactions in order to monitor future changes and ensure sustainable management of land and wildlife in this region.

[6] Data accessed online at: http://www.climate.weatheroffice.ec.gc.ca, on June 1, 2009.

Knowledge Gaps:

- Little information is available on the productivity of this range.
- The impact of climate change on the Northern Richardson Mountain Dall's sheep population is unknown.

4.0. Harvest and Non-Consumptive Uses

4.1. Traditional Use

Because they are associated with steep slopes, high peaks, and relatively inaccessible terrain, Dall's sheep are notoriously challenging to hunt. Hunting Dall's sheep can be dangerous, and experienced hunters sometimes ambushed sheep at river crossings and in shrubs, where the escape terrain is generally more distant and the access easier (Gwich'in Elders 1997). Because Aklavik is the nearest community to the Northern Richardson Mountains, most sheep hunters are based in Aklavik. Eighteen interviews conducted with Elders and harvesters in the Gwich'in Settlement Area (Shaw *et al.* 2005) suggested that at least 130 sheep were harvested between the 1930s and the 1990s, mostly in the 1950s and 1960s. This is likely an artefact of the age of the interviewees, with the most active hunting period coinciding with their middle years. Interestingly, of the 9 persons who reported hunting sheep (C. Lambert Koizumi, unpublished data), about half of the harvest was attributed to 2 hunters, who were apparently highly skilled in sheep hunting. Most of the harvest was done in the wintertime, with access facilitated by dog teams in the earlier days, and more recently by snowmobile. Moreover, the harvest tended to be equally distributed between adult ewes and rams, with very few lambs and younger animals taken (Shaw *et al.* 2005). This was a subsistence harvest, and in times of scarcity, hunters would take whatever animals were available to them. When the hunters could choose, the rams were sometimes preferred because they had more meat; but, after the rut, the ewes were fatter and tastier (Gwich'in Elders 1997). After a sheep was harvested, its muscles and organs were consumed (heart, kidney, liver and stomach; the lungs were dog food); its hide was used to make clothing, blankets or babiche; its gall bladder was used as a wound-healing medicine; and its horns were carved into various tools (e.g. spoons, forks, knife handles, fishing hooks) (Gwich'in Elders 1997).

4.2. Contemporary Harvest Levels

Inuvialuit in the Inuvialuit Settlement Region and Gwich'in in the Gwich'in Settlement Area have preferential rights to the harvest of Dall's sheep, which means that their basic needs level has to be fulfilled before harvest can be allocated to other groups, such as residents and non-residents hunters (as described in the Inuvialuit Final Agreement, the Gwich'in Comprehensive Land Claim Agreement). The Vuntut Gwitchin First Nation Final Agreement does not make specific reference to sheep or sheep harvest, but sheep are addressed by the general provisions of the agreement.

In the Yukon, the Vuntut Gwitchin community of Old Crow is the primary user group of Dall's sheep in the Northern Richardson Mountains, and there is only a small level of harvest. There has been no harvest of Dall's sheep reported by the Vuntut Gwitchin in the last 3 years (Vuntut Gwitchin, unpublished data). Anecdotal information indicates a minimum of 11 sheep taken in the last 12 years (S. Foss, Vuntut Gwitchin Government, personal communication). Between 2004 and 2006, Yukon Government issued 2 annual resident hunting permits for full curl rams valid in a limited area on the Yukon side of the Northern Richardson Mountains. One kill was reported in each of 2004 and 2005 (J. Carey, unpublished information). At the request of other stakeholders, these 2 permits were not issued in 2007 and 2008, while the management plan for this population was being developed and harvest recommendations formulated. Two permits were issued in 2009; 1 ram was reported killed (J. Carey, unpublished information).

In the Northwest Territories, there is only aboriginal harvesting from this population. There are no limits or conditions on aboriginal harvest of Dall's sheep, and reporting is voluntary. However, export permits are required to take wildlife parts out of the Northwest Territories. Also, aboriginal hunters are encouraged to bring all skulls to their local renewable resource office so that the horns can be plugged. This is a requirement for skulls leaving the Territories.

As mentioned in the preceding section, most users of this population come from the community of Aklavik; however the communities of Fort McPherson, Inuvik, and Tsiigehtchic also harvest Dall's sheep. Current harvest information is not available for the whole population, but a minimal harvest is available from the horn plug records (Environment and Natural Resources, Government of the Northwest Territories), the Inuvialuit Harvest Study (The Joint Secretariat 2003), the Gwich'in Harvest Study (GRRB 2009), and the Inuvialuit Harvest Data Collection Program (Aklavik Hunters and Trappers Committee (HTC)). Overall, the harvest reported in the

1970s was greater than the levels reported in recent years (Figure 8).

From 1966 to 1977, an estimated total of 329 sheep were harvested, with an annual average of 33 (range: 5 to 62), according to Simmons (1973) and estimates from the Northwest Territories Government (letter from W. C. Cleghorn, Indian and Northern Affairs, Ottawa ON, dated May 30 1977). Harvest information is then missing until the Inuvialuit Harvest Study, which ran from 1987 until 1997. During that time, there was an estimated average harvest of 2 sheep per year (range: 0 to 4), for a total of 15 Dall's sheep, all of which were harvested by Inuvialuit members of the Aklavik community (The Joint Secretariat 2003). The final report of the Gwich'in Harvest Study, conducted from 1995 to 2001, reported a Gwich'in participant harvest of 9 Dall's sheep between 1995 and 1999 (range: 0 to 5 per year) (GRRB 2009), although the published estimate may be revised to be 10 Gwich'in participant harvests (K. Callaghan, personal communication). Harvest by non-Gwich'in indigenous people also documented in this study was 11, for a total of 20 sheep harvested. This harvest by non-Gwich'in indigenous people was not included in other sources of harvest records used in this report (K. Callaghan, unpublished information). Thirteen of the harvested sheep were rams, 4 were ewes, and 3 were of unknown sex. Most of the harvest (N = 14) was reported by Aklavik hunters, followed by Fort McPherson (N = 4), Inuvik and Tsiigehtchic (N = 1 each). The Aklavik HTC and Yukon Government estimated a small annual harvest between 2001 and 2006 (average: 1.3; range: 0 to 4; unpublished data). A large portion of the reported harvest of Dall's sheep occurred in the Black Mountain area near Aklavik. In the Inuvialuit Harvest Study and the Aklavik HTC Harvest Study, 78% and 75% respectively of sheep harvested were harvested from Black or Red Mountain. In the Gwich'in Harvest Study, this proportion was 90% (K. Callaghan, unpublished information).

Concerns have been raised in the community of Aklavik about a change in hunting practices where sheep are now being harvested for the commercial value of the cape and horns. In 2006, an Aklavik hunter was charged and convicted for meat wastage in Yukon; it was purported to be a subsistence kill, but the harvester took the cape and horns and left all of the meat behind (J. Carey, unpublished information). There has been an increase in sheep parts exported from the Inuvik region during this past decade. There was a yearly average of 3 sets of horns exported from 2000 to 2003, which increased to 7 in 2004, and 9 in 2005 and 2006. There were also 3 hides exported without horns attached between 2000 and 2004; and this number also rose in 2005 and 2006, to 3 and 5 respectively (ENR export permits, unpublished information).

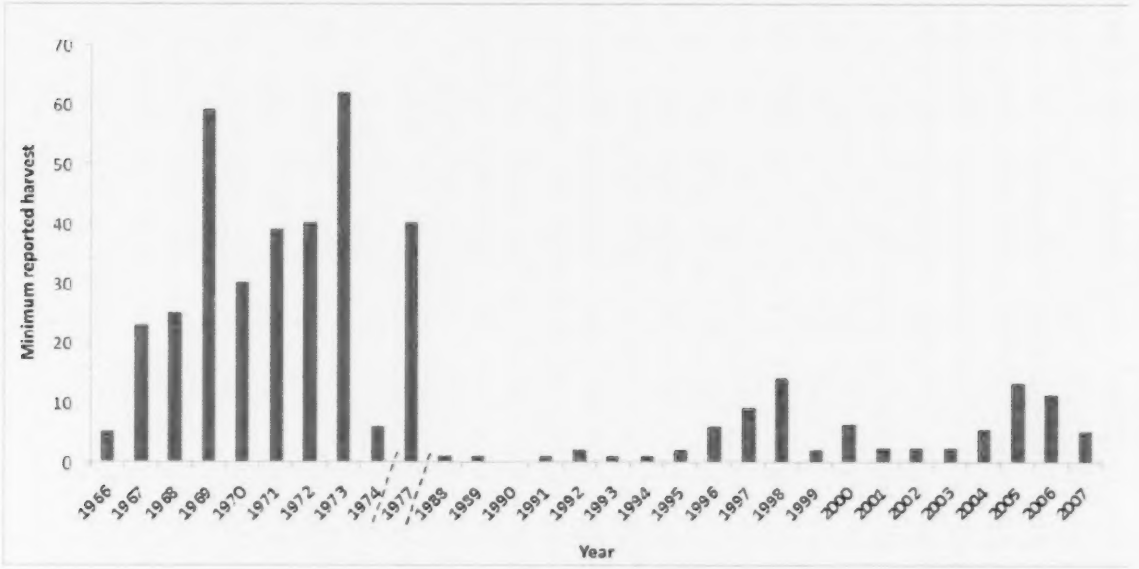

Figure 8. Minimum reported harvest between 1966 and 2008, with few missing years (as indicated by the dashed lines). The estimates come from Simmons (1973), the Inuvialuit Harvest Study (2003), the Gwich'in Harvest Study (unpub. data & GRRB (2009)), statistics from Environment and Natural Resources, Government of the Northwest Territories (unpub.), and the Aklavik HTC Harvest Study. Some of the export data might be missing, and not all harvest was reported. Based on anecdotal information, the Vuntut Gwitchin average was estimated at 1 per year from 1995 until 2008.

The harvest levels reported here are deemed minimum estimates. Recent efforts to ensure all hunters know the requirement to plug horns have significantly reduced the number of unreported kills. Recent community meetings (2005 – 2006) in Aklavik and Fort McPherson have highlighted concerns related to a potential overharvest of Dall's sheep by some harvesters. Meat wastage, caused by exclusive interest in rams with large horns for their economic or trophy value, has also been reported. The Ehdiitat Renewable Resources Council, in collaboration with the Gwich'in Renewable Resources Board and Environment and Natural Resources (Government of the Northwest Territories), recommended a closer monitoring of sheep harvest to detect such situations and ensure that Dall's sheep harvest remains within sustainable limits (unpublished, from 2005 – 2006 consultations).

4.3. Estimated Impact of Harvest

In the 1970s, Simmons (1973) was concerned that the population of Dall's sheep in the Northern Richardson Mountains was over-harvested. At the time, he estimated that harvest rates were 11% higher than the recruitment rate of the population, and therefore the harvest was not sustainable. If the aerial survey abundance estimates

were correct in 1971, 1972, and 1973 (Table 1), between 8% and 60% of the adult population was actually harvested during these years. Simmons (1973) recommended better harvest monitoring and improved cooperation between hunters and wildlife managers. Nolan and Kelsall (1977) and Hoefs (1978) later reiterated his concerns.

In comparison, recent records show a much lower harvest. If we use the maximum reported value of 14 harvested individuals (in years 1998 and 2005), and apply this harvest level to the most recent (2006) population estimate (N = 704 – 97 lambs – 46 unclassified – 22 yearlings = 539 adults), the annual harvest would represent approximately 2.6% of the adult population. Based on the demographic rates of Dall's sheep in the Northern Richardson Mountains in the 1980s, Barichello *et al.* (1987) recommended a harvest rate of 2.5% of the adult population. However, the suggested 2.5% rate was based on a harvest of full curl rams only, which is the regulation applicable for licensed harvest by resident and non-resident hunters in Yukon. In the case of aboriginal hunting, immature rams and ewes are also harvested. Based on statistics from the Inuvialuit Harvest Study (The Joint Secretariat 2003), the Gwich'in Harvest Study (GRRB 2009) and statistics from Government of the Northwest Territories export permits (Environment and Natural Resources, unpublished data), the sex ratio of harvested sheep was about 1 ewe for 4 rams for the past 2 decades. In many cases, there is inadequate information on the age of the animals taken, so the proportion of full-curl ram harvest versus immature rams is unknown.

There is some controversy over the consequences of a selective full curl ram harvest, versus the mixed harvest of sex and age classes in mountain sheep populations. The removal of ewes and rams younger than full curl can have a profound effect on recruitment and population growth since the reproductive value of these individuals, as actual and future contribution to population growth, is higher than that of full curl rams. In such a scenario, a sustainable harvest rate may in fact be much lower than the proposed 2.5%. This said, a full curl ram harvest only is not necessarily better, since it targets individuals of prime age that are most actively engaged in the rut (Geist 1971). The rams with larger horns socially dominate the younger or smaller rams, and by being reproductively active, are the ones passing their genes on to the next generation. For bighorn sheep (*O. canadensis*) populations that are under a sport hunting regime, it has been demonstrated that older rams, or even the younger individuals that have faster horn growth, have lower survival rates due to harvest mortality (Bonenfant *et al.* 2009). This selective harvest could counter natural selection processes and lead to some important undesirable consequences at the evolutionary scale, such as reductions in body

weight and horn size of rams in the population over time (Coltman *et al.* 2003). Additionally, at very high harvest levels, the loss of most or all of the larger rams could disturb the social structure of the population and favour a higher female ratio and a younger age of males, leading to higher energy expenditures of males during the rut (Singer and Zeigenfuss 2002), which could ultimately depress the recruitment rates (Milner *et al.* 2007).

However, the examination of horns from over 8,000 rams in the southern Yukon indicated that horn growth is positively correlated with climate patterns and habitat productivity (Hik and Carey 2000, Loehr *et al.* 2010), suggesting that the removal of larger rams does not necessarily interfere with the capacity of producing high quality rams in the future. Investigations of hunted versus unhunted Dall's sheep populations in Alaska indicated no impact of older ram removal on population productivity, nor on younger rams' survival (Murphy *et al.* 1990). Rams with larger horns are usually close to the end of their life, and the hunting mortality of this older age class could be compensatory (i.e. the rams would have otherwise died of natural cause) (Hoefs 1984*a*). This argument seems to be supported by the horn measurements of rams that died from hunting and from natural causes in the southern Yukon (Hik and Carey 2000, Loehr *et al.* 2007): in either case, rams with faster horn growth were dying earlier. This supports the idea that there is a natural tradeoff between growth rate and longevity, and the selective hunting of large rams may have effects similar to natural mortality. A detailed assessment of sustainable harvest rates for this population has been regarded as necessary by the partners of the management plan for this Dall's sheep population.

4.4. Non-consumptive Use

Interest in this Dall's sheep population is not only for harvest. Despite the sheep population being located in a range with limited access, community members and the public in general, greatly value the presence of sheep in the Northern Richardson Mountains and find it gratifying to know that there are Dall's sheep in these mountains (C. Lambert Koizumi, unpublished results from Gwich'in Renewable Resources Board management questionnaire 2005). A number of people are also interested in viewing or photography opportunities. Some hunters and families from adjacent communities camp regularly in the area, monitoring the number of sheep year after year, and watching for any unusual events disturbing to this population or its habitat. Tourists from the Northwest Territories, Yukon, and elsewhere also venture into the Northern Richardson Mountains, sometimes through aircraft or boat access, and

can spend days (or weeks) hiking, skiing, or paddling the range. This type of adventure tourism can be very lucrative for the local communities, and some people have expressed the wish to keep a section of the mountains unhunted and undisturbed by other activities, which would facilitate viewing opportunities and support non-consumptive usage of this Dall's sheep population (C. Lambert Koizumi, unpublished results from Gwich'in Renewable Resources Board management questionnaire 2005).

Knowledge Gaps:

- There is inadequate information about the number, sex, age, harvest location, and date of Dall's sheep harvested in the Northern Richardson Mountains.
- The current sustainable harvest rate for this population is unknown.

5.0. Education and information exchange

The management plan for Dall's sheep in the Northern Richardson Mountains emphasizes the importance of educating youth in the nearby communities in regards to Dall's sheep and keeping communities informed about research and management plans. As such, the following activities are important and may ultimately contribute to the conservation of this Dall's sheep population: participation of community members (harvesters, youth, elders, etc.) in field studies; visits and public talks by Dall's sheep researchers in schools and community halls; school trips bringing students on the sheep range (e.g. as the Moose Kerr School students, in Aklavik, have done in previous years); updates from renewable resource officers and councils to the communities; documentation of local and traditional ecological knowledge; and frequent exchanges about the status and concerns related to this population.

In the NWT, the Gwich'in Renewable Resources Board and the Fort McPherson, Aklavik and Tsiigehtchic RRCs receive reports on the status of sheep based on the research projects conducted by the GRRB biologist. These reports are also provided to the Wildlife Management Advisory Council (NWT). These groups are also involved in deciding what information needs to be collected. The research is jointly funded by the Gwich'in Renewable Resources Board, Environment Yukon and Environment and Natural Resources, GNWT.

The implementation of these activities is an ongoing process contingent on the goodwill of

individuals involved in the research and management of this Dall's sheep population, and facilitated by permitting processes that are guided by legislation (for example, the acquisition of a wildlife research permit in the Northwest Territories is associated with the obligation of producing a plain language research summary for the communities). As much as possible, individuals and organizations should be encouraged to share information and involve each others in the process of managing and conserving Dall's sheep in the Northern Richardson Mountains, for the greatest benefit of this population.

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Appendix: List of Identified Knowledge Gaps

- The genetic structure of this Dall's sheep population and its genetic relationships with other thinhorn sheep populations have not been investigated;
- For most surveys conducted so far, neither the observation error nor the visibility correction factor was assessed. Such indices would increase the accuracy and provide confidence limits to the population estimates;
- Annual variations in population size and composition are not available and would help to detect population trends (increase or decline) more promptly. A combination of ground and aerial surveys could yield such information in a cost-effective way, but would need to be designed properly to optimize data quality and minimize disturbance to Dall's sheep;
- The accuracy of productivity estimates for this population is impaired by irregularity of survey timing. A more consistent timing of the surveys would increase the quality of the estimates and facilitate their comparison between years;
- Little is known about the age at first reproduction of both ewes and rams in this population;
- It is currently unclear what the driving factors for this population are. In particular, knowledge is limited on:
    - the influence of weather on the abundance and fluctuations of this population;
    - the importance of density dependence as well as competition interactions (habitat overlap and resource partitioning) with other species, particularly muskox;
    - numbers of predators in the Northern Richardson Mountains, and what the quantifiable effects of wolves, grizzly bears, golden eagles, and other predators may be on this population;
    - emerging diseases and parasites in this population;
    - impacts of research on this population;
- Little information is available on the productivity of this range;
- The impact of climate change on the Northern Richardson Mountain Dall's sheep population is unknown;
- There is inadequate information about the number, sex, age, harvest location and date of Dall's sheep harvested in the Northern Richardson Mountains;
- The current sustainable harvest rate for this population is unknown.